

BAM Nuttall Ltd

Victoria North HIF Infrastructure Works

Controlled Waters Detailed Quantitative Risk Assessment Report

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This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Executive Summary

This report has been prepared by Arup on behalf of BAM Nuttall Ltd (BAM) to present detailed assessment of the risks to controlled waters associated with ground contamination at the Victoria North HIF Infrastructure site, to support the Ground Investigation Report (GIR) and the Remediation Strategy for the proposed HIF Infrastructure works.

Manchester City Council (MCC) and Far East Consortium International Ltd (FEC) have submitted planning application 133143/VO/2022 to include remediation of the HIF Infrastructure site for future development including: earthworks and remediation to create suitable development platforms; the construction of new internal access roads; new utility and services connections; and the provision of green infrastructure including green links and the first phase of a new city river park.

A series of ground investigations have been completed to inform the redevelopment of the area for housing by a joint venture between MCC and FEC. A detailed review of the history of the site and the findings of the ground investigations are presented in the Arup GIR.

This report references three primary site areas, known as: Red Bank Plateau (an area constructed by filling during the late 1800s to create railway sidings); St. Catherine’s Wood (an area comprising wooded slopes extending down to the banks of the River Irk) and Red Bank Terrace (a generally flat area currently occupied by a variety of commercial operations and car parking).

The Arup GIR identified a number of primary contamination sources within the HIF Infrastructure site boundary, however, three areas of particular focus were identified:

- A historical railway gas storage facility on Red Bank Plateau. Ground investigations in this area encountered perched groundwater with an oily sheen and occasional hydrocarbon contaminated soils. Contaminants identified in the ground and groundwater in excess of screening values in this area include petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH), cyanide and ammoniacal nitrogen which are typical coal gas contaminants. Groundwater contaminated with hydrocarbons has been detected downgradient of the gasworks, suggesting that mobile contamination is migrating from the gasworks source towards the River Irk.
- A former railway carriage shed was located on Red Bank Plateau in the north of the site. Hydrocarbon contamination, including NAPL, TPH and PAH was noted in groundwater perched in relic foundations. Observations of shallow hydrocarbon contamination in soil and perched groundwater correlated with the former footprint of the carriage shed.
- Historical mapping identified two former reservoirs or water features that were shown on maps dating from 1848 to 1906 in the south-western part of the site, which as the 1922 maps indicated were infilled by a significant thickness of made ground when Red Bank Plateau was formed; the features are now between 4 and 10m below current ground level. Strong hydrocarbon odours were noted in material believed to be within the base of one of the former reservoirs (the southern feature), and groundwater monitoring wells installed in the southern reservoir detected the presence of hydrocarbons (TPH and PAH) in the groundwater. No evidence of hydrocarbon contamination was noted in the northern reservoir.

A review of the potential source-pathway-receptor linkages determined that the gasworks area directly overlies the former river channel of the River Irk, the Alluvium and Collyhurst Sandstone, meaning there may be a direct linkage connecting this source to the Principal Aquifer and River Irk. The Glacial Till is absent in this area and is therefore not protecting the aquifer beneath. Contamination consistent with the made ground has been detected in groundwater in this area. DQRA was carried out using the Environment Agency’s Remedial Targets Methodology (RTM) to evaluate the contaminants of concern.

The former railway carriage shed is located on made ground which directly overlies the Manchester Marl. In addition to the Glacial Till in this area the upper part of Manchester Marl has weathered to a clay which will also prevent significant vertical migration of contamination. The Manchester Marl is not considered to be a receptor for the purposes of this DQRA. The hydrocarbon contamination was observed to be perched oily groundwater within relic foundations and contaminated soils within the footprint of the former carriage shed. A pathway for contamination to reach the River or Principal Aquifers is not considered to be present, therefore DQRA was not carried out for this

source. However, remediation of this area will be required, comprising excavation of grossly contaminated soils and validation sampling, with associated removal of contaminated groundwater from excavations as necessary.

A review of the ground investigation information concluded that the southern historical reservoir/water feature, whilst hydrocarbons are present in the basal deposits, is not causing significant groundwater contamination with hydrocarbons. The infilled reservoirs are at depth and are not proposed to be disturbed by future development; they are located in an area that is proposed for public open space. No remediation is proposed in relation to these features.

Re-use criteria were derived for site-won soils to be placed within St, Catherine’s Wood or Red Bank Terrace. This is because these areas are in close proximity to the river and where soils are excavated from another part of the site (for example, Red Bank Plateau), it is considered prudent to ensure that such materials will not pose an unacceptable risk to the River Irk. Two sets of re-use criteria (Zone 1 and Zone 2) were generated for fill derived elsewhere within the HIF Infrastructure site that is placed within St. Catherine’s Wood or Red Bank Terrace, depending on the distance from the river to where the soils are to be re-used. These re-use criteria are designed to be protective of controlled waters, assuming that contaminants are the metals, TPH and PAH fractions identified in the initial screen of the data. Re-use criteria have not been derived for materials that are excavated within Red Bank Plateau and recovered for re-use within the Red Bank Plateau area. In addition, re-use criteria have not been derived for material within St Catherine’s Wood and Red Bank Terrace that is to be locally redistributed during regrading works.

A Remediation Strategy and Verification Plan is to be developed for the HIF Infrastructure works by BAM, informed by the outcome of this DQRA. The following actions need to be carried forward into that document:

- Gross hydrocarbon contamination will need to be removed from the site, where encountered, including within the former carriage shed area and the excavation verified. This is likely to include perched contaminated shallow groundwater (e.g. with floating NAPL) and NAPL-contaminated soils;
- Remediation is required within the former ‘gasworks’ area, including excavation of subsurface structures and associated contamination. The remedial targets to be met are set out in **Section 8.2** of this report. The Remediation Strategy should include frequency of testing and approach to data interpretation;
- During works to re-naturalise the river banks through St Catherine’s Wood, inspections should be undertaken to identify any visual or olfactory evidence of the discharge of contaminants from higher permeability material associated with the former river meander bend or from the face of the regraded river banks. If either of these are encountered, consideration should be given to the adoption of measures to address these potential contaminant linkages (for example, the provision of low permeability material at appropriate locations along the river banks);
- Materials sourced from elsewhere within the site that are re-used within St. Catherine’s Wood and Red Bank Terrace should be tested to ensure they achieve the proposed materials re-use criteria, as set out in **Table 10** and **Table 11** of this report, which have been determined on the basis of the distance from the banks of the River Irk in which fill is to be placed. The Remediation Strategy should include frequency of testing and approach to data interpretation;
- Implementation of a discovery strategy during remediation to ensure that any previously unforeseen areas of contamination are identified and dealt with and are not taken for re-use as fill elsewhere within the site. In addition, any historic water wells that are encountered during the discovery strategy should be sealed.

1. Introduction

1.1 Background and purpose of report

This report has been prepared by Ove Arup & Partners Ltd (Arup) on behalf of BAM Nuttall Ltd to present detailed assessment of the risks to controlled waters associated with ground contamination at the Victoria North HIF Infrastructure site, to support the Ground Investigation Report (GIR) [1].

A planning application has been made by Avison Young on behalf of Manchester City Council to include remediation of the HIF Infrastructure site for future development including the following main elements:

- Earthworks and remediation to create suitable development platforms;
- The construction of new internal access roads;
- New utility and services connections; and
- Provision of green infrastructure including green links and the first phase of a new city river park.

In the area referred to as Red Bank Plateau, earthworks will be a combination of excavation and filling operations. In the Red Bank Terrace and St Catherine’s Wood areas, earthworks will be predominantly limited to regrading operations, with only limited filling operations requiring import of soils from other areas.

The purpose of this report is to present additional controlled waters detailed quantitative risk assessment (DQRA), carried out to generate remediation targets for the primary source areas identified within the site and calculate controlled waters driven re-use criteria for excavated soil that is to be used as fill within the site. The DQRA will inform a remediation strategy for the HIF Infrastructure application and generate appropriate reuse criteria for recovered soils. This report should be read in conjunction with the Arup Ground Investigation Report (GIR) [1] to avoid repetition of content. This report addresses comments from the Environment Agency (EA) on the Preliminary Arup GIR [2] relating to risks to controlled waters.

1.2 Previous assessments and reports

A Preliminary Ground Investigation Report (GIR) [2] was prepared using the results of the 2019 and 2021 AEG ground investigations [3] [4], which included a generic controlled waters risk assessment. The GIR provides the first stage of assessment of contamination as required by the planning process. The report used desk study information and ground investigation data to review the site history, uses of the site that might have caused ground contamination, the environmental sensitivity of the site and the risks the contamination might present to the development and controlled waters.

A third phase of ground investigation was subsequently completed in 2022 at the site by BAM under the supervision of Arup, which is reported in the BAM factual report [5]. The results from this investigation have been used to prepare an updated version of the GIR [1].

1.3 Scope and objectives

In the GIR [1] Arup noted that a detailed controlled waters risk assessment should be carried out to:

- Support groundwater contamination risk assessments to understand remediation requirements, remediation cost estimates and timescales;
- Evaluate which sources of contamination are a priority for treatment and to use this to inform the remediation strategy for Victoria North HIF Infrastructure scheme;
- Assess whether groundwater contamination originating within the HIF Infrastructure site is posing a risk to controlled waters;
- Satisfy Environment Agency regulatory requirements and enable discharge of planning condition(s) relating to land contamination.

1.4 Planning applications and conditions

Manchester City Council (MCC) and Far East Consortium International Ltd (FEC) have submitted planning application 133143/VO/2022 for the proposed main HIF Infrastructure works within the site. Arup has been provided with a copy of the Environment Agency’s recommended planning conditions relating to this application, which require:

- Additional ground investigation [Note this requirement is addressed by the BAM 2022 GI];
- Additional risk assessment [Note this requirement is aimed to be addressed by this report, in conjunction with the GIR];
- A remediation strategy and a verification plan;
- Verification of remediation;
- No infiltration of surface water drainage into the ground where the ground is adversely affected by contamination;
- Written consent from the local planning authority for piling using penetrative methods;
- Notification of the local planning authority of any unexpected contamination identified during the works.
- These conditions are not unusual and are commonly applied to brownfield sites.

1.5 Limitations

This report has been prepared by Arup for use by BAM Nuttall Ltd. It should not be relied upon by any third party except as provided for in Arup’s appointment with BAM. Arup has based this report on the sources detailed within it and believes them to be reliable but cannot and does not guarantee the authenticity or reliability of third-party information.

Reasonable skill and care have been exercised in preparation of this report in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team in undertaking this contamination assessment, it is possible that ground conditions and contamination other than that potentially indicated by this report may exist at the site.

This report has been prepared based on current legislation, statutory requirements, planning policy and industry good practice at the time of writing. Any subsequent changes or new guidance may require the findings, conclusions and recommendations made in this report to be reassessed in the light of the circumstances. Should the proposed earthworks, layout or use of the site change, the assessments and conclusions presented in this report may need to be revised.

2. The Site

2.1 Site location and description

The Victoria North HIF Infrastructure site is located in the Red Bank area of Manchester, to the north of Manchester Victoria railway station. It is centred at approximate national grid reference SJ846996, see **Figure 1**.



Figure 1 Victoria North HIF Infrastructure site (red outline) and proposed development plots

This report references three primary site areas as shown in **Figure 2**. The Site comprises the Red Bank Plateau (circa. 40mOD to 43mOD), which was constructed by filling during the late 1800s to create railway sidings. From the plateau, wooded slopes (St Catherine’s Wood) extend down to the banks of the River Irk at circa. 30mOD. Along the north-eastern boundary, slopes extend down towards the adjacent Packaging Products site beyond the site boundary. The majority of the plateau is proposed for residential development. There is a plot in the north-eastern corner (Plot RB05b) of St. Catherine’s Wood which is currently proposed for a school development.

The plateau is separated from the Red Bank Terrace area in the southwest part of the Site by a slope (circa 9m high). Red Bank Terrace is generally flat, circa 31mOD, and currently occupied by a variety of commercial operations and car parking. This area is also planned for residential development, with the slope area designated for public realm.

A series of ground investigations [3] [4] [5] have been completed to inform the redevelopment of the area for housing by a joint venture between Manchester City Council (MCC) and the Far East Consortium International Ltd (FEC). A detailed review of the history of the site and the findings of the ground investigations are presented in the Arup GIR [1], which should be read in conjunction with this report.

2.2 Geology

2.2.1 Summary

The geology of the HIF Infrastructure site has been assessed as part of the GIR [1] and is described in detail in that report. The descriptions below are based on the assessment presented in the GIR and forms the basis for the groundwater risk assessment modelling presented later in this report. **Drawing 1** and **Drawing 2** contain cross-sections through the site, illustrating the general ground model and the changes in topography that occur from the Red Bank Plateau to St. Catherine’s Wood and Red Bank Terrace. The line of the sections is shown on **Drawing 3**.

2.2.2 Made ground

On the Red Bank Plateau, the ground surface is variable, comprising areas of hardstanding in the north of the area and dense vegetation in the south.

The made ground on the plateau area has been measured up to 15.7m thick. The uppermost metre of made ground generally comprises sandy gravel, and the deeper made ground is highly variable, but has a more cohesive component and is generally described as sandy slightly gravelly clay, clayey sand and gravel, or gravelly sand. Similar ground conditions in the made ground have been recorded in the St. Catherine’s Wood area, with the upper metre being granular with a more cohesive content beneath.

On the lower areas of the site (referred to as Red Bank Terrace), the made ground is generally thinner than on the plateau (between 1.8m and 6.4m thick) and is described as granular (sandy gravel or gravelly sand) with clayey material in some areas.

2.2.3 Alluvium

The alluvium is variable in composition and described as medium dense slightly gravelly sand and soft sandy clay or clayey sand. Alluvium is limited in extent, being mostly encountered close to the River Irk and in buried river channels and is recorded as between 0.3m and 4.7m thick.

2.2.4 Glacial till

The glacial till is described as soft to firm, becoming stiff at depth, slightly sandy gravelly clay. Granular bands have been identified within the till, described as medium dense to very dense brown slightly clayey sandy gravel and gravelly sand. Glacial till is locally absent within Red Bank Terrace and adjacent to the River Irk, but was encountered beneath the Red Bank Plateau and St. Catherine’s Wood. The thickness of this stratum was recorded as between 0.3 and 10.5m.

2.2.5 Bedrock

According to published British Geological Survey (BGS) mapping [6], the bedrock beneath the site is formed of three units: the Chester Pebble Beds Formation in the southern part of the site, the Manchester Marls Formation through the centre and the Collyhurst Sandstone Formation in the north. The Collyhurst Sandstone is shown on mapping to dip 5 degrees in a south-westerly direction, beneath the Manchester Marl. There is a fault running through the centre of the site within the Manchester Marl, downthrown to the south-west.

From ground investigation, the extent of the Manchester Marl within the site boundary is greater than shown on the BGS mapping, with the Collyhurst Sandstone only outcropping in the north-eastern corner of the site. Approximate bedrock boundaries based on the ground investigation observations are shown in **Drawing 3**.

The Manchester Marl formation thickness is given by the BGS as between 15 and 45m, the Collyhurst Sandstone formation thickness is quoted as ranging from 0-300m and the Chester Pebble Beds formation thickness up to 420m [7].

Ground investigation has found that the uppermost part of all bedrock units is weathered. The Chester Pebble Beds is described in the field as a red brown slightly clayey coarse-grained sandstone; the Manchester Marls as a thinly laminated clayey mudstone and the Collyhurst Sandstone as a fine to coarse grained sandstone with lenses of red marl.

2.3 Proposed development

For the purposes of this report, the site area is taken to be the HIF Infrastructure Works planning boundary and this report refers only to the planning application site. The site boundary is outlined in red in **Figure 2** below.



Figure 2 Proposed development boundary and main site areas

As shown on **Figure 2** and described above, the planning application site has been divided into the three areas listed below:

- Red Bank Plateau
- Red Bank Terrace
- St Catherine's Wood

The HIF Infrastructure Works proposals comprise:

- Earthworks and remediation to create suitable development platforms;
- The construction of new internal access roads;
- New utility and services connections;
- Provision of green infrastructure including green links and the first phase of a new city river park.

The earthworks and remediation to be undertaken as part of the HIF Infrastructure works will consist of the following activities:

- Removal of relic structures including the remains of a former carriage shed and a gasworks. During these works, contaminated soil and perched groundwater are anticipated and these primary source areas will therefore, require remediation and validation. The former gasworks area has been subject to DQRA to generate remedial targets, as described in **Section 5**. The former carriage shed has not been subject to DQRA, for the reasons discussed in **Section 4.4**.
- Regrading existing slopes between Plots RB02 and RB03 and the River Irk (**Figure 1**);
- Lowering ground levels in Plots RB02 and RB03;
- Filling activities across Red Bank Plateau to produce the required development platform;
- Regrading existing slopes in Red Bank Terrace to facilitate a series of new accessible footpaths;
- Regrading existing slopes in St Catherine's Wood to facilitate a series of new accessible footpaths and;
- Limited import of fill materials in Red Bank Terrace and St Catherine's Wood to supplement the regrading operations and achieve the required landform.

These earthworks activities are summarised in **Drawing 8**.

Remediation for the HIF Infrastructure works will be limited to mitigating identified risks to controlled waters only. Land contamination risk assessment and remediation associated with plot-specific development requirements will be undertaken under a separate later application.

This DQRA derives controlled waters remediation targets (soil validation criteria) for:

- Activity 1. Excavations in the gasworks area, and;
- Activities 2. and 3. which will lead to the generation of soil arisings that are potentially suitable for re-use as engineering fill within the site. These will be assessed and managed as follows:
 - Site-won soils proposed for re-use as part of Activity 4 (Red Bank Plateau only) will be subject to the requirements of the earthworks specification alone and to comply with the requirements of waste management legislation.
 - Site-won soils proposed for re-use as part of Activity 7 (Red Bank Terrace and St Catherine's Wood) will be subject to the requirements of the reuse criteria derived in this DQRA.

Given the findings of ground investigation reported in the Arup GIR [1] and the established history of the site, in which the made ground used for the construction of Red Bank Terrace has been in place for as much as 150 years, the re-use criteria proposed in this DQRA will not be applied to materials that are re-used in the area from which they were excavated. Soils will not therefore, be screened against the proposed re-use criteria in the following circumstances:

Soils recovered by excavation in Plots RB02 and RB03 that are re-used elsewhere on Red Bank Plateau.

Soils that are locally relocated as part of the regrading activities proposed within Red Bank Terrace and St Catherine's Wood.

Soils that are obviously/grossly contaminated will not be re-used and the methodology for dealing with soils in these circumstances shall follow the procedures detailed within the HIF Infrastructure works Remediation Strategy.

The criteria proposed in this DQRA will however, be used in the following circumstances, to demonstrate that proposed fill materials will not raise or introduce new risks to controlled waters:

- Soils that are excavated from one area of the site (e.g. Red Bank Plateau) and used as fill in another area (e.g. Red Bank Terrace or St Catherine's Wood). Re-use criteria have been generated for Activity 7 as follows:
- Material that is to be placed within 50m of the River Irk (Zone 1).

- Material that is to be placed within a zone that is between 50m and 130m from the River Irk (Zone 2).

These zones are illustrated on **Drawing 9**.

Although it is unlikely that regrading works will involve the relocation of soils from one zone to another, soils relocated into Zone 1 adjacent to the river (**Drawing 9**) will also need to comply with the relevant re-use criteria.

The proposed drainage strategy for the development is for all surface water to drain directly into the River Irk, with no infiltration drainage except in the parkland areas of St. Catherine’s Wood, which will continue to drain by infiltration, as is the current situation. A detention basin is also proposed within the St. Catherine’s Wood area.

Ultimately, the HIF Infrastructure works site is to be developed for a predominantly residential use with landscaped areas of public open space. The development plot areas and the landscaping are described in the current proposed masterplan presented in **Figure 1**. The proposed follow-on development in each of the three site areas (**Figure 2**) is as follows:

- Red Bank Plateau – The current masterplan indicates that this will be the focus of proposed residential development within the site. Limited areas of private residential gardens are proposed within the plateau area.
- Red Bank Terrace (the area shaded blue on **Figure 2**) – this area is to be predominantly formal public open space with planted areas, connecting footpaths and cycleways and areas of public realm.
- St. Catherine’s Wood - The current masterplan indicates that this area will be generally non-residential, with a school proposed in the north of the area (Plot RB05b) and areas of public open space elsewhere. Outside Plot RB05b, existing vegetation is to be preserved as fully as possible with limited areas of enhancement to facilitate the proposed POS use, including planted areas, connecting footpaths and cycleways and areas of public realm.

A planning application has not yet been submitted for any follow-on development within the site area. This is due to be submitted in late 2022 for the end-uses described above. Development specific remediation criteria to determine suitability for use will be finalised as part of a later application.

2.4 Regulator engagement

The Environment Agency has been engaged from an early stage in the Victoria North scheme and were provided with the Desk Study and Preliminary GIR [2] for comment. The findings of the Preliminary GIR were presented to the EA in a workshop held online in January 2022 and the EA provided written comment on the GIR in February 2022 (see **Appendix A**). The EA comments received are summarised as follows:

- Historical groundwater abstraction boreholes are likely to have been associated with the industries on the site. These boreholes are unlikely to have been decommissioned adequately and may present preferential contaminant linkages into the underlying bedrock aquifer. The EA recommended that relevant records are consulted to assess the possibility of this (see **Section 3.2**).
- There is clear evidence that the former gas storage facility (termed ‘gasworks’ throughout this document, although note that no evidence has been identified that this was a coal gas manufacturing plant) has had an adverse impact on the water environment and creation of suitable remedial target concentrations and land remediation is likely to be required. The former river channel may be acting as a pathway for mobile contamination to migrate elsewhere within the site that will need further assessment (see **Section 3.3**).
- Removal of the river bank at St. Catherine’s Wood should not result in the degradation of the River Irk (see **Section 7.2**).
- Further assessment and sampling should be undertaken to the carriage shed and basal infilled waterbodies (reservoirs) to determine needs for remediation (see **Section 3.1**).
- Develop receptor-driven remedial targets that are protective of controlled waters (see **Appendix B** and discussion in **Section 5**).

This report aims to respond to these queries and comments from the Environment Agency.

3. Hydrogeological Conceptual Model

3.1 Sources

3.1.1 Overview

The Arup GIR [1] provides a list of on-site primary contamination sources identified across the HIF Infrastructure site. These include a former railway gas storage facility (marked on maps as a ‘gasworks’), railway infrastructure including a carriage shed, dye and other chemical works associated with the textile industry. Made ground is extensive across the site and has been used to infill a former meander of the River Irk in the northern part of the site and a historical mill race that extends the length of the site. Significant quantities of made ground were imported in the late 1800s in order to create what is now referred to as Red Bank Plateau.

Ground investigations completed by AEG in 2019 [3] and 2021 [4], and by BAM in 2022 [5] have confirmed that contamination in the soil and groundwater is widespread across the site. Although some defined contamination sources have been identified from desk-based information, it is likely that contamination is also present as a result of the imported made ground used to create Red Bank Plateau.

A detailed evaluation of the data was undertaken to identify potential contaminants of concern in soil and groundwater, which is reported in the Arup Preliminary GIR [2]. This presented generic quantitative assessments of soil and leachate data that identify various contaminants across the site at concentrations in excess of generic standards.

Three areas of particular focus were identified following the initial review of GI data from the 2019 and 2021 investigations. These were targeted for further investigation by BAM during the 2022 investigation:

Gasworks

A historical railway gas storage facility (marked on maps as a ‘gasworks’, although no evidence has been identified that this was a coal gas manufacturing plant, rather a local storage facility for gas produced elsewhere), which was shown on historical mapping published between 1906 and 1964, was present in the northeast of the site, on the top of Red Bank Plateau. Ground investigations in this area in 2021 encountered perched groundwater with an oily sheen, hydrocarbon contaminated soils and a ‘metallic blue sand’. The ‘metallic’ description is thought to refer to the fact that there was a sheen on the soil, which may be related to the hydrocarbon contamination that was present rather than metals. Contaminants identified in the ground and groundwater in excess of screening values in this area include petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH), cyanide and ammoniacal nitrogen which are typical coal gas contaminants. Groundwater contaminated with hydrocarbons has been detected downgradient of the gasworks, suggesting that mobile contamination is migrating from the gasworks source towards the River Irk.

The gasworks area was investigated further by BAM in 2022 using trenching methods, to determine the extent of relic foundations, and borehole drilling, to look at deeper ground conditions and install monitoring wells. Further observations of oily contamination were made in the subsurface of the gasworks area, which have been cross-referenced with historical plans showing the gasworks buildings. A sample of perched groundwater recovered from one of the trenches (TT301) was analysed and confirmed the presence of complex cyanide, ammoniacal nitrogen and the PAH compounds fluoranthene, anthracene and benzo(a)pyrene in excess of water quality standards. The outline of the gasworks buildings is shown in **Drawing 4** and correlates well with the observations of surface contamination made during the ground investigations.

Carriage shed

A former railway carriage shed was located on Red Bank Plateau in the north of the site. Hydrocarbon contamination, including NAPL, TPH and PAH was noted in groundwater perched in relic foundations. Observations of shallow hydrocarbon contamination in soil and perched groundwater correlated with the former footprint of the carriage shed, which is shown in **Drawing 5**.

Infilled reservoirs

Historical mapping identified two former reservoirs or water features that were shown on maps dating from 1848 to 1906 in the south-western part of the site, which as the 1922 maps indicated were infilled by a significant thickness

of made ground when Red Bank Plateau was formed; the features are now between 4 and 10m below current ground level.

Strong hydrocarbon odours were noted in material believed to be within the base of one of the former reservoirs (the southern feature in **Drawing 5**), where two boreholes have been drilled: BH314 and BH211A. Both encountered a strong hydrocarbon odour in made ground, but these did not extend into the underlying glacial till, which was approximately 0.8m thick beneath the reservoir over the Chester Pebble Beds sandstone.

Groundwater monitoring wells installed in the southern reservoir detected the presence of hydrocarbons (TPH and PAH) in the groundwater in BH211A, but not in BH314. Where detected, concentrations of TPH were not in excess of water quality standards. Fluoranthene and Benzo(a)Pyrene were present in groundwater in BH211A at concentrations which exceed WQS, but exceedances of the WQS for these PAH compounds are present in shallow groundwater across the site.

The northern reservoir was investigated by BH210. No evidence of hydrocarbon contamination was noted in this reservoir and no contamination was noted in BH105, which was drilled slightly to the north. Groundwater quality was tested within the Chester Pebble Beds bedrock immediately beneath this reservoir and was found to be of good quality and likely to reflect the quality of upgradient groundwater entering the site.

Reused material as a source

As discussed in **Section 2.3**, material that will be recovered for re-use as fill within Red Bank Plateau, or material that will be locally redistributed during regrading operations, will not be screened against the re-use criteria developed in this DQRA. This is because there is no evidence to indicate that water quality within the primary receptor (the River Irk) is being adversely impacted by existing ground conditions at the site and that local re-distribution of existing materials will not introduce new contaminant linkages or raise risks to controlled waters.

Where material is to be relocated from one area of the site to another (e.g. from Red Bank Plateau to St Catherine’s Wood), there is the potential for new contamination risks to be introduced and for re-used material to act as a potential source of contamination.

3.2 Receptors

3.2.1 Groundwater

Groundwater receptors in the site were identified in the Arup GIR [1] as follows:

- Secondary A aquifer in the Alluvium associated with the River Irk;
- Secondary (undifferentiated) aquifer in the Glacial Till;
- Secondary B aquifer in the Manchester Marl;
- Principal aquifers in the Collyhurst Sandstone and Chester Pebble Beds.

The hydrogeology of the HIF Infrastructure site has been assessed based on the ground investigation data. Two aquifers have been identified at the site, which are termed the shallow aquifer and the deep aquifer in this report. These units are separated by glacial till (where present).

Shallow aquifer

The shallow aquifer is formed of made ground and alluvium. The made ground is continuous and extends across the entire site area. The made ground is described as variable, containing granular and cohesive materials. There is some near-surface perched groundwater within the made ground associated with relic structures, but this is not a continuous groundwater body. Groundwater is present at the base of the made ground, perched above the lower permeability glacial till, or in continuity with the alluvium where made ground rests directly over the alluvium.

The alluvium is present only in the area immediately adjacent to the River Irk, but includes a historical course of the River Irk which has been overtipped by made ground in the north of the site, see **Drawing 5**.

The alluvium is defined as a Secondary A aquifer by the EA, likely because it provides some base flow to the River Irk, however it is of very limited extent.

A piezometric surface for the shallow aquifer is presented in **Drawing 6** and suggests groundwater flow reflects the surface topography and flows towards the River Irk to the southeast. Groundwater monitoring within wells on the HIF Infrastructure site show shallow groundwater levels range across the study area from around 40mOD at the top of Red Bank Plateau to 28mOD in St. Catherine’s Wood and 27mOD at Red Bank Terrace.

In situ hydraulic testing has been carried out within the strata that form this aquifer. The testing is described in the Contractor’s Factual Report on the GI [3] and is summarised in Section 5 of the GIR [1]. The permeability of the alluvium in isolation was only measured in one well, at 7.53E-09m/s (0.0007m/day), where the alluvium was described as a dense sand. The made ground is generally more permeable, ranging from 5.68E-08m/s to 3.26E-05m/s with an average permeability of 0.6m/day.

The made ground and alluvium groundwater quality is affected by contamination, which is likely to be the result of historical industrial uses within the site and surrounding area. The shallow aquifer has not been considered as a receptor for the purposes of DQRA primarily as the alluvium is very limited in extent and predominantly cohesive.

Aquitard (Glacial Till)

The glacial till deposits, present across the majority of the HIF Infrastructure site, act as an aquitard separating the shallow aquifer from the deep groundwater in the bedrock below. The glacial deposits are described as sandy gravelly clay becoming stiff with depth. A number of granular bands have been recorded within the glacial till, which are described as medium dense to very dense slightly clayey sandy gravel/gravelly sand with a low to moderate cobble content. Groundwater has been encountered within the granular bands of the glacial till.

Within the HIF Infrastructure site, the thickness of the glacial till is proven to be between 1.1 and 6m. The glacial till deposits are absent within the river valley (St. Catherine’s Wood area of the site) where they have been scoured by the River Irk and replaced by alluvium, or locally where no till is present made ground directly overlies the bedrock.

Where present, this aquitard is considered to provide a significant barrier preventing recharge of units below, but where absent (along the River Irk valley), the shallow and deep aquifers may be in continuity.

The Glacial Till has not been considered as a receptor for the purposes of DQRA due to its predominantly low permeability, aquitard characteristics.

Deep aquifer

As described in **Section 2.2.5**, three distinct bedrock types are present within the site boundary: the Collyhurst Sandstone, which outcrops along the northern edge of the site; the Manchester Marls in the northern part of the site, and the Chester Pebble Beds in the southern part of the site (see **Drawing 3**).

The BGS Aquifer Properties Manual [7] describes the Collyhurst Sandstone Formation as a dune-bedded aeolian sandstone. The geological map [6] shows the Collyhurst Sandstone dipping gently (5 degrees) to the south-west, beneath the Manchester Marl. The Manchester Marl Formation is a mudstone that represents a marine incursion from the north. The Chester Pebble Beds overlies the Manchester Marl and is part of the Sherwood Sandstone Group, the major aquifer within this region. The Sherwood Sandstone Group is described as generally poorly cemented with high porosities.

The BGS hydrogeological map of the Cheshire Basin (reproduced as **Figure 3** below) shows the regional groundwater flow direction in the Sherwood Sandstone is towards the southwest [8] and groundwater levels in the Sherwood Sandstone Group (of which the Chester Pebble Beds is part) in the vicinity of the site are around +30mOD. This matches site observations of the groundwater levels in the deep aquifer in the Chester Pebble Beds, shown in **Drawing 7**, which show groundwater levels between 32 and 27mOD.

The Collyhurst Sandstone Formation only outcrops in a very small part of the HIF Infrastructure site. Two monitoring wells with a response zones in the Collyhurst Sandstone had a piezometric level of around 28mOD.

Piezometric heads within the bedrock strata indicate that groundwater within the deep aquifer flows towards and discharges to the River Irk.

Both the Collyhurst Sandstone and Chester Pebble Beds are classified as Principal aquifers by the EA and are an important groundwater resource locally. Groundwater is abstracted from the Collyhurst Sandstone approximately 270m north-east of the site (hydraulically upgradient) by Packaging Products Ltd for general cooling. Groundwater is abstracted from the Chester Pebble Beds approximately 400m north-west of the site (upgradient) by Derby

Brewery for cooling and process water. These sandstone groundwater bodies are considered to be receptors for the purposes of DQRA.

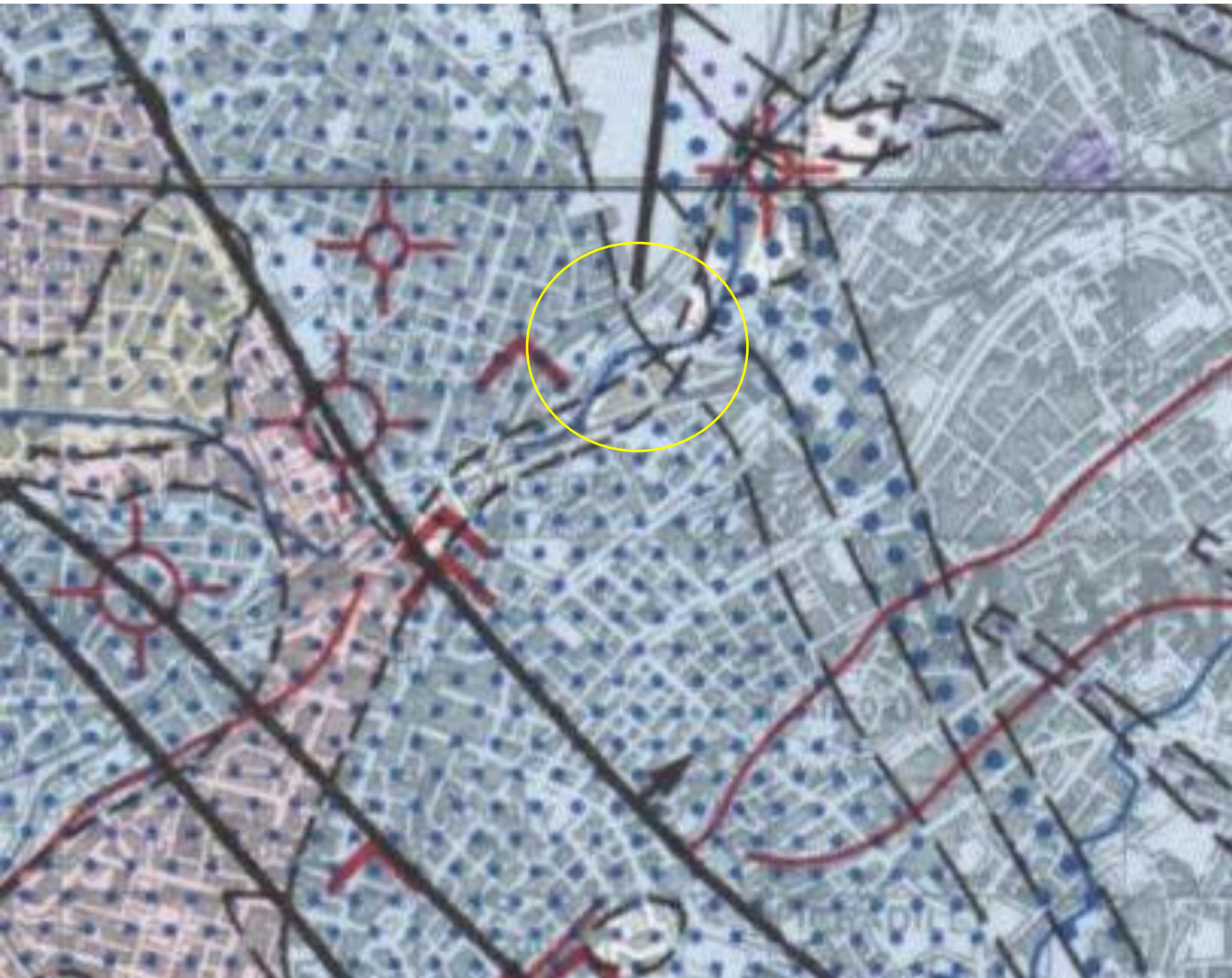


Figure 3 Extract from the hydrogeological map of Clwyd and the Cheshire Basin [8]

The Manchester Marl Formation is considered by the BGS to be an aquiclude [9], preventing the mixing of groundwater between the two sandstone units. The Manchester Marl is classified by the Environment Agency as a Secondary B aquifer however in the vicinity of the site it is an aquiclude with no resource potential and is not considered likely to be providing significant baseflow to the River Irk. It is not considered to be a receptor for the purposes of this DQRA.

3.2.2 Surface water

There is one surface watercourse close to the study area, the River Irk. This is located along the south-eastern boundary of the HIF Infrastructure site. The river course has been historically straightened where it passes the site, as historical mapping shows an old meander bend that is now buried beneath the plateau area (see **Drawing 5**). The River Irk flows from north-east to south-west past the site, entering a culvert beneath the active Network Rail viaduct (outside the HIF Infrastructure site boundary), before emerging for a short distance, passing over Scotland Weir and then entering Victoria culvert beneath the railway station. The confluence with the River Irwell is approximately 500m downstream of the HIF Infrastructure site.

The ground investigation data suggests that the river is in hydraulic continuity with both the alluvium and the sandstone aquifers. There is a visible outcrop of the Chester Pebble Beds sandstone to the south of the Victoria North HIF Infrastructure site within the channel of the River Irk.

There is no current surface water drainage system operating within the site boundary, therefore surface water currently infiltrates through the ground or runs off into the River Irk. The edges of the Red Bank Plateau are formed of very steep slopes, which are likely to be encouraging runoff in these areas of the site.

The River Irk was considered to be the primary receptor in the initial screening of groundwater data as it is considered to receive discharge from the adjacent groundwater bodies, see **Section 5.2**.

3.2.3 Other receptors

Other receptors identified in the Arup GIR [1] include future site residents, users, on site buildings, materials and services and soft landscaping. Risks to these receptors are not considered further in this controlled waters DQRA report but assessment of the risks to other receptors are detailed in the GIR and necessary mitigation will be detailed in the Remediation Strategy.

3.3 Pathways

3.3.1 Controlled waters pathways

Potential pathways identified in the Arup GIR [1] include:

- Runoff during construction;
- Vertical migration of dissolved phase contamination;
- Lateral migration of contamination in groundwater (shallow and deep);
- Lateral and vertical migration of NAPL.

This DQRA for controlled waters focuses on the evaluation of the soil leaching pathway and the lateral migration of existing dissolved phase contamination to the River Irk. It does not include any detailed modelling of risks associated with runoff, or the lateral and vertical migration of NAPL (as potentially mobile NAPL has not been identified by ground investigation). Further consideration will be given to these potential pathways within the Remediation Strategy by implementation of appropriate construction site management practices, including a rigorous discovery strategy during ground works.

3.3.2 Soil leaching pathway

The potential for contaminants to leach from soil will depend on both the presence of a leachable source in soil and a vertical flow of infiltrating water between the source and underlying groundwater. Future uses of the site include the construction of buildings, hardstandings, roads and areas of parkland. Rates of infiltration will vary according to the permeability of the surface and sub-surface materials. This potential pathway has been considered in the DQRA to evaluate the known source of soil contamination within the former gasworks area and the need for remediation.

A separate evaluation has been completed of potential leaching from materials that are proposed for reuse as part of the proposed cut and fill activities shown in **Drawing 8**.

3.3.3 Lateral migration of dissolved phase contamination

The potential for existing sources of dissolved phase contamination within the shallow and deep groundwater to migrate and cause significant impact at chosen compliance points has been assessed in this DQRA.

The highest concentrations of dissolved phase contamination have been associated with the former carriage shed and gasworks site. Levels of contamination in the two sandstone aquifers are generally lower than those observed in the shallow groundwater.

3.3.4 Vertical migration of dissolved phase contamination

The DQRA focuses on an evaluation of lateral migration within the aquifers, based on the site’s hydrogeological setting, as this is expected to be more significant than the potential for vertical migration.

As discussed in **Section 3.2.1**, the glacial till is expected to be acting as an aquitard to prevent significant downwards migration of contamination from the shallow groundwater into the underlying bedrock. The review of groundwater data within the site confirms that the quality of groundwater within the bedrock under the Red Bank Plateau, where

glacial till is present, is better than that within the lower-lying areas of the site where the covering of glacial till is absent. Furthermore, the conceptual site model defines the River Irk as the receptor for discharge of groundwater from the bedrock strata.

3.3.5 Preferential pathways

Preferential pathways are physical features that serve to provide a route by which contaminants have the potential to migrate more rapidly through the subsurface, often by-passing normal physical barriers and reducing potential attenuation.

Possible preferential pathways within the HIF Infrastructure site are the former meander of the River Irk beneath the gasworks site and a former mill race that extends the length of the site beneath the Red Bank Plateau (see **Drawing 5**). When operational the meander bend and mill race were connected. The former meander may be having an impact on groundwater movement locally to the gasworks, although the groundwater level monitoring was inconclusive. Several monitoring wells have been installed within the meander and mill race which have identified dissolved phase contamination with hydrocarbons and cyanide within the groundwater in the alluvium, which suggests that it may be acting as a preferential pathway for contamination to move away from the gasworks site.

As requested by the EA (see **Section 2.4**), a search for records of historical water wells was carried out within the current HIF Infrastructure site boundary, by reviewing of BGS water well records and borehole logs, the BGS hydrogeological map and historical mapping [1][8]. No records of wells were identified, but the former mill race and River Irk is likely to have provided the former industries in the St. Catherine’s Wood area with water. The HIF Infrastructure ground works will include extensive site turnover and will therefore identify any historical water wells that may be present. The Remediation Strategy will include a discovery strategy that ensures any historical water wells encountered are appropriately sealed to prevent them acting as a preferential pathway.

3.3.6 Other pathways

Other pathways identified in the Arup GIR [1] include preferential pathways being created by future piled foundations when the site is eventually developed. There will need to be a Foundation Works Risk Assessment (FWRA) completed prior to any future piling works within the site, which will be addressed to discharge planning conditions associated with the future planning application for development of the site. This pathway is not considered further in this DQRA.

3.4 Potential pollutant linkages

Based on the review of ground investigation information, the source-pathway-receptor linkages have been reviewed as follows, with a view to determining the need for DQRA:

3.4.1 Gasworks

The gasworks area directly overlies the former river channel of the River Irk, the Alluvium and Collyhurst Sandstone, meaning there is a direct linkage connecting this source to the Principal Aquifer and River Irk. The Glacial Till is absent in this area and is therefore not protecting the aquifer beneath. Contamination consistent with coal gas waste has been detected in groundwater in this area. The former river channel may be acting as a preferential pathway for contamination to migrate to other areas of the site. There is a need to address the contamination in the former gasworks for the protection of controlled waters, therefore this linkage will be assessed in the DQRA.

3.4.2 Carriage shed

A former railway carriage shed is located on made ground which directly overlies the Manchester Marl. In addition to the Glacial Till in this area the upper part of Manchester Marl has weathered to a clay which will also prevent significant vertical migration of contamination. The Manchester Marl is not considered to be a receptor for the purposes of this DQRA. The hydrocarbon contamination was observed to be perched oily groundwater within relic foundations and contaminated soils within the footprint of the former carriage shed. A pathway for contamination to reach the River or Principal Aquifers is not considered to be present, therefore DQRA has not been carried out for this source. However, remediation of this area will be required, comprising excavation of grossly contaminated soils and validation sampling, with associated removal of contaminated groundwater from excavations as necessary. This will be addressed in the Remediation Strategy.

3.4.3 Infilled reservoirs

A review of the ground investigation information has concluded that the northern reservoir is not contaminated and the southern reservoir, whilst hydrocarbons are present in the basal deposits, is not causing significant groundwater contamination with hydrocarbons. The infilled reservoirs are at depth and are not proposed to be disturbed by future development; they are located in an area that is proposed for public open space. The cross-section in **Drawing 2** shows that the southern reservoir is partially overlain by cohesive, lower permeability made ground which may be helping to isolate the basal material from the surrounding groundwater. No remediation is proposed in relation to these features and therefore DQRA has not been carried out for this source.

3.4.4 Made ground to be re-used

Despite the long-standing industrial nature of the site [26], the phases of ground investigation that have been undertaken within the site [1] have not identified widespread significantly elevated concentrations of contaminants in made ground. Areas of the site which have been identified as potentially high risk, such as the former ‘gasworks’, have been the subject of repeated and targeted assessment to verify the findings of previous phases of ground investigation. On the basis of the findings of the various phases of ground investigation that have been undertaken, only one source area has been identified that is considered to pose an unacceptable risk to controlled waters, the former ‘gasworks’ area. The general absence of identifiable contaminant ‘hotspots’ within the wider site is considered to be consistent with the site’s history, in which the made ground material has been present over timescales in the order of 150 years.

Ground investigation has established that the groundwater quality across the site is impacted, which is likely to be the result of historical industrial activities within the site and the immediate surrounding area, together with the placement of imported made ground to form Red Bank Plateau. The intrusive investigations have identified that the shallow and deep groundwater bodies are likely to discharge into the River Irk. Despite this however, repeated rounds of surface water quality monitoring have consistently demonstrated that there is no detectable evidence of water quality in the River Irk being impacted by existing ground contamination as it flows through the site (**Section 4.2.3**).

The future development proposals on Red Bank Plateau are for high-rise residential blocks, new roads and predominantly hardstanding. The development will not have infiltration drainage and surface water is proposed to discharge into the River Irk. This proposed hardstanding is significantly more extensive than has been the case historically and therefore, once the site is developed, infiltration will be substantially reduced across the Red Bank Plateau area. Overall therefore, the proposed development itself will reduce the potential for continued mobilisation of residual contaminants in the made ground.

Within the St. Catherine’s Wood and Red Bank Terrace areas of the site, the proposals are for the creation of public open space and a river park (with the exception of Plot RB05b in St. Catherine’s Wood, which is proposed for a school end use). These areas of the site have dense existing tree coverage and although some tree removal is required in order to deliver the HIF works, tree removal is to be limited to preserve the existing ecological conditions (the slopes adjacent to Plots RB02 and RB03 have limited existing tree cover). These proposals, are considered not to introduce any significant change to the source-pathway-receptor linkages that have been identified for these areas of the site, and therefore, there is no potential for additional mobilisation of residual contaminants from within the made ground.

Given the sensitivity of surface watercourses, notably the River Irk, it is considered appropriate however, to safeguard controlled waters from potentially mobile contaminants that may be associated with new fill materials potentially emplaced close to the river. Soils that are excavated from one area of the site and used as fill within St. Catherine’s Wood or Red Bank Terrace, will therefore, be screened against the re-use criteria presented in this DQRA. Two sets of re-use criteria have been generated depending on the distance from the river in which the soils are to be placed (**Drawing 9**). **Table 1** summarises the pollutant linkages to be considered in the DQRA.

Table 1 Summary of pollutant linkages to be considered in DQRA

PCL	Description	Highest risks (without mitigation)	Further assessment / risk management
1	Risk of pollution to the River Irk, during and after development, from existing made ground	Moderate to high risk	Evaluation of groundwater flow characteristics and relative groundwater and surface water levels confirms that groundwater in both the shallow and deep aquifers are likely to discharge into the River Irk. The quality of the River Irk does not appear to be affected by the current groundwater conditions, but in cases where soils are excavated from one part of the site (e.g. Red Bank Plateau) to be re-used in either St. Catherine’s Wood or Red Bank Terrace (which are the areas closest to the River Irk), the re-used material has been subject to DQRA to generate re-use criteria that are protective of the river.
2	Risk of pollution to shallow (Secondary A) aquifer - Alluvium	Negligible risk	As discussed in Section 3.2.1 the alluvium is not considered a receptor in the DQRA due to its very limited extent and predominantly cohesive characteristics.
3	Risk of pollution to Secondary (undifferentiated) aquifer – Glacial Till	Negligible risk	As discussed in Section 3.2.1 the Glacial Till is not considered a receptor for the purposes of DQRA due to its predominantly low permeability, aquitard characteristics. No continuous groundwater body is present within the Till and it is not considered to provide significant base flow to the River Irk.
4	Risk of pollution to Secondary B aquifer – Manchester Marl	Negligible risk	As discussed in Section 3.2.1 the Manchester Marl is not considered a receptor for the purposes of DQRA. It is not considered to provide significant base flow to the River Irk, is of no resource potential and in the vicinity of the site forms an aquiclude.
5	Risk of pollution to deep aquifer - Chester Pebble Beds, Collyhurst Sandstone	Moderate to high risk	DQRA has been undertaken to assess risks presented by existing soil contamination within the former gasworks area to the Principal Aquifer.

4. Controlled Waters Risk Assessment

An assessment has been carried out to determine if existing sources of contamination present a significant risk to controlled waters and if so, to determine remedial targets for the site.

4.1 Selection of contaminants of concern

There are no Generic Assessment Criteria (GAC) available for the direct assessment of contaminants in soil applicable to controlled waters. Therefore, evaluation of groundwater data has been completed to identify contaminants of concern and possible sources of soil contamination that present a risk of impacts to the underlying Principal Aquifers and River Irk.

The approach to assessing risks posed by contamination is outlined in the Environment Agency’s land contamination guidance [10]. Assessment of risks to water resources is completed in general accordance with the Environment Agency Groundwater Protection guidance [11] for England and Wales.

The Environment Agency has developed specific guidance known as the Remedial Targets Methodology (RTM) [12] for the tiered assessment of risks to controlled waters. The first stage of quantitative risk assessment is undertaken by an initial screening of reported leachate and/or groundwater/surface water concentrations against

selected published water quality standards (WQS) for potential contaminants of concern to identify those contaminants which warrant further detailed investigation.

The WQS are selected to assess potential risks to the controlled water receptors identified in the preliminary conceptual site model. The WQS can be derived in several ways with consideration to:

- whether the substance is classified as hazardous or non-hazardous under the Water Framework Directive (2000/60/EC) and Groundwater Daughter Directive (2006/118/EC) (discussed further in **Appendix B**);
- background concentrations in the aquifer; and
- published guidance such as Environmental Quality Standards (EQS) that are protective of surface waters or the Water Supply (Water Quality) Regulations 2016 that are protective of drinking water.

Where groundwater contamination has been identified, the general approach is to use a published environmental standard which is relevant to the current or intended use of the aquifer. The following regulations and guidance have been referenced to select appropriate WQS for controlled waters:

- Environmental Quality Standards (EQS) for fresh water listed in the Water Framework Directive (WFD) 2015 [13]
- Other values not listed in WFD and taken from EA operational EQS [14]
- UK Drinking Water Standards (UK DWS) [15]
- EU Drinking Water Standards (EU DWS) [16]
- World Health Organisation (WHO) drinking water standards [17], [18]
- United States Environmental Protection Agency (USEPA) 2018 drinking water standards [19] and national aquatic life criteria [20]

4.2 Groundwater quality

The groundwater quality within the site was monitored as part of the two most recent ground investigations, by AEG in 2021 [4] and BAM in 2022 [5]. Groundwater data has been split into two sets, for the deep and shallow aquifers, as shown in **Table 2** and **Table 3** below.

The groundwater data has been collected from standpipes with response zones within the various strata beneath the site. In determining contaminants of potential concern, the average concentration of each contaminant has been calculated. Where the average concentration of a contaminant is less than the WQS, that contaminant is not considered further in this risk assessment. Contaminants where the average concentration exceeds the WQS are highlighted in the tables below.

4.2.1 Shallow groundwater

Shallow groundwater data is based on testing of water from the made ground and alluvium, which are in continuity along the River Irk edge of the site where glacial till is absent. Fewer samples were taken of alluvium compared to made ground, because this stratum is not present across the entire site area and is confined to the area close to the River Irk (see records in **Appendix C**).

Testing of groundwater from the made ground identified that exceedances of cadmium, manganese, nickel, zinc, ammoniacal nitrogen and PAH are widespread across the site. Other less frequent exceedances were noted for antimony, chromium, lead, selenium, cyanide and TPH.

Cyanide analysis was typically carried out for total cyanide, but given the historical land uses on the site, speciated analysis was undertaken for complex cyanide, free cyanide and thiocyanate on selected samples. The WQS used for cyanide is based on hydrogen cyanide (HCN) which exists in a free state and therefore the WQS is appropriate for free cyanide. Free cyanide was only detected occasionally in groundwater above the limit of detection. The same WQS was also used to assess total cyanide but not complex cyanide. The cyanide speciation, where undertaken, shows that the total cyanide is mostly formed of cyanide complexes.

Although thiocyanate can occur as an environmental contaminant in its own right (e.g. from mining and electroplating) more often it occurs in conjunction with cyanide sources. In the presence of sulphur, complex forms of cyanide can breakdown to produce less toxic thiocyanate. In acidic media, thiocyanate can breakdown to form hydrogen cyanide, however this is not expected to occur at the Victoria North HIF Infrastructure site where the prevalent conditions are neutral to slightly alkaline. Because of its lower environmental toxicity and the absence of relevant water quality standards, thiocyanate it is not considered to require separate fate and transport modelling. Cyanide has therefore been discounted from further assessment on the basis that free cyanide is not typically detected in groundwater beneath the site and the cyanide that is present is in complex form, which is likely to break down into less toxic thiocyanate.

TPH was detected in shallow groundwater in various locations across the site, but the highest concentrations were in BH102 (in the centre of Red Bank Plateau, hydraulically downgradient from the carriage shed and gasworks), BH204 (gasworks), BH211A (infilled reservoir) and BH315 (gasworks). Very light hydrocarbons in the range C5-C8 were generally not detected in shallow groundwater, except in BH315 in the gasworks area, where low concentrations of benzene were present. Xylenes were detected in shallow groundwater in BH102. No visible evidence of hydrocarbons was noted in BH102 and BH315 during drilling in the superficial deposits or groundwater, although subsequent groundwater sampling noted a slight sheen on the groundwater at BH102. PAH compounds are also present in groundwater in these locations. Because hydrocarbon contamination was not noted in the overlying superficial deposits, it is conjectured that contamination is migrating in groundwater from an upgradient source, likely to be the former gasworks or carriage shed.

The exceedances noted for antimony, lead and selenium were based on single locations and the average concentrations for this contaminant do not exceed the GAC. They are therefore discounted from further assessment.

Contaminants of concern in shallow groundwater identified from the screen against published WQS are as follows:

- Cadmium
- Chromium
- Copper
- Iron
- Manganese
- Nickel
- Zinc
- Ammoniacal nitrogen as N
- TPH – Aliphatic fractions C8-C16, aromatic fractions C8-C35
- PAH (fluoranthene, anthracene, benzo(a)pyrene)

4.2.2 Deep groundwater quality

A summary of the groundwater quality within the two sandstone aquifers beneath the site is presented in Table 5. Because these two aquifers are separated by the Manchester Marl and are not anticipated to be in contact with each other, the results have been separated. This screening has identified exceedances of:

- Cadmium
- Chromium
- Copper
- Lead
- Manganese
- Zinc
- Ammoniacal nitrogen
- TPH Aliphatic C12-C16
- TPH Aromatic C12-C16
- PAH and
- bis(2-ethylhexyl)phthalate.

These contaminants are virtually identical to those present in the shallow groundwater, suggesting that the two groundwater bodies (shallow and deep) are in continuity with each other where glacial till is absent close to the River Irk.

The TPH exceedances were only noted in the Collyhurst Sandstone, which is present beneath the former gasworks area in the north-eastern part of the site. No exceedances of the WQS for TPH were noted in the Chester Pebble Beds, even though hydrocarbons had been identified in the former reservoirs. As Glacial Till is present beneath the reservoirs, it appears that it has prevented significant quantities of hydrocarbon from entering the Chester Pebble Beds groundwater. Both groundwater bodies are impacted by PAH contamination at similar concentrations. One exceedance of the WQS for Bis(2-ethylhexyl)phthalate was noted in the Collyhurst Sandstone groundwater in the area of the former gasworks. The source of this contamination is not known, but it was not detected in any other samples selected for semi-volatile organic compound (SVOC) testing in excess of the WQS and therefore its presence is not considered to be widespread across the site, therefore it is discounted from further assessment.

Table 2 Summary of contaminants in excess of WQS in the shallow groundwater

Response zone strata (Units)	WQS Value (mg/l)	Shallow groundwater data from site sampling			
		No. of samples	No. > WQS	Average	Maximum
Antimony	0.005	27	1	0.0015	0.01
Arsenic	0.05	27	3	0.019	0.192
Beryllium	0.004	27	1	0.00009	0.006
Cadmium	0.00015	27	12	0.001	0.0115
Chromium	0.0047	27	4	0.029	0.74
Copper	0.03375	27	2	0.038	0.84
Iron	1	5	1	4.28	19.7
Lead	0.00958	27	3	0.14	3.61
Manganese	0.226	27	21	3.66	15
Nickel	0.01607	27	9	0.17	0.098
Selenium	0.01	27	3	0.004	0.037
Vanadium	0.02	27	2	0.013	0.217
Zinc	0.03728	27	14	0.15	1.61
Ammoniacal nitrogen as N	0.6	27	18	4.51	22
Aliphatic C8-10	0.3	21	2	0.99	21.4
Aliphatic C10-12	0.3	21	2	1.77	38
Aliphatic C12-16	0.3	21	3	3.94	81.8
Aromatic C8-10	0.3	21	1	0.43	9
Aromatic C10-12	0.09	21	3	1.02	21.3
Aromatic C12-16	0.09	21	6	2.43	48.1
Aromatic C16-21	0.09	21	3	1.52	29
Aromatic C21-35	0.09	21	3	0.64	12.4
Fluoranthene	0.0000063	21	20	0.003	0.027
Naphthalene	0.002	21	1	0.0009	0.013
Anthracene	0.0001	21	8	0.0008	0.0044
Benzo(a)pyrene	1.7E-07	21	14	0.0035	0.049

Table 3 Summary statistics for contaminants in excess of WQS in the deep groundwater

Response zone strata (Units)	WQS Value (mg/l)	Collyhurst Sandstone				Chester Pebble Beds			
		No. of samples	No. > WQS	Average	Maximum	No. of samples	No. >WQS	Average	Maximum
Antimony	0.005	No samples > GAC				6	1 (BH212)	0.003	0.006
Cadmium	0.00015	5	2 (BH203)	0.00019	0.0003	6	2 (BH212)	0.0007	0.0038
Chromium	0.0047	No samples > GAC				6	1 (BH212)	0.008	0.045
Copper	0.03375	5	1 (BH203)	0.014	0.043	6	1 (BH212)	0.017	0.078
Iron	1	No samples > GAC				3	2 (BH210, RE15)	0.99	1.65
Lead	0.00958	5	2 (BH310, BH203)	0.025	0.088	6	2 (BH212, RE15)	0.16	0.87
Manganese	0.226	5	5 (BH310, BH203)	1.08	1.92	6	5 (BH210, BH212, RE15)	0.72	1.6
Nickel	0.01607	5	1 (BH203)	0.006	0.02	6	1 (BH212)	0.007	0.024
Vanadium	0.02	No samples > GAC				6	1 (BH212)	0.005	0.03
Zinc	0.03728	5	3 (BH310, BH203)	0.05	0.14	6	1 (BH212)	0.16	0.92
Ammoniacal nitrogen as N	0.6	5	5 (BH310, BH203)	2.63	4.04	6	2 (BH210)	1.36	7.4
Aliphatic C12-16	0.3	5	2 (BH310)	0.9	3.32	No samples > GAC			
Aromatic C10-12	0.09	5	1 (BH310)	0.03	0.11	No samples > GAC			
Aromatic C12-16	0.09	5	2 (BH310)	0.36	1.35	No samples > GAC			
Fluoranthene	0.0000063	5	4 (BH310, BH203)	0.0002	0.0003	5	4 (BH212, BH210, RE15)	0.0002	0.00013
Naphthalene	0.002	5	1 (BH203)	0.00001	0.0085	No samples > GAC			
Anthracene	0.0001	5	1 (BH203)	0.00004	0.00012	No samples > GAC			
Benzo(a)pyrene	1.7E-07	5	2 (BH310, BH203)	0.00014	0.0003	5	2 (BH212, RE15)	0.00014	0.00006
Bis(2-ethylhexyl)phthalate	0.0013	5	1 (BH203)	0.009	0.0052	No samples > GAC			

4.2.3 Background water quality

The use of published conservative WQS enables an initial assessment of results. Results that are above the WQS do not necessarily represent a risk to controlled waters and alternative lines of evidence can be considered, such as comparison against background or upgradient groundwater and surface water concentrations or regional water quality, discussed below.

The site is located in an industrial area of central Manchester and numerous historical industrial activities present potential contamination sources in the vicinity of the site. Groundwater in the region has been affected by anthropogenic contamination, discussed below.

Background/upgradient groundwater quality

Baseline hydrochemistry for the Permo-Triassic sandstones in the region have been published by the BGS for some of the contaminants of concern identified in this screening exercise [8]. However, there are no BGS-reported baseline concentrations for many of the contaminants present in groundwater beneath on the site. Therefore, to determine background groundwater quality, upgradient boreholes have been identified within the site boundary:

- Collyhurst Sandstone: no upgradient boreholes are available, as this stratum outcrops in the northern end of the site where groundwater quality is already affected by hydrocarbon contamination, likely due to the presence of a former gas storage site (labelled as a gasworks on plans) in this location;
- Chester Pebble Beds: borehole BH210 is present on the Red Bank Plateau area, which is located in an upgradient area of the site.

Water quality in the River Irk was measured on four separate occasions as part of the ground investigations in May 2021 and on three occasions in March 2022 at a point upstream of the site, in the centre of the site and downstream. A summary of the concentrations of contaminants of concern in the River Irk are presented in **Table 5**.

The background concentrations are presented in River Irk water quality below against the average concentrations measured in groundwater on site. Where site concentrations exceed background concentrations/upgradient concentrations, they have been highlighted. The concentrations of the contaminants of concern do not vary greatly from upstream of the site to downstream, indicating that the site is not having a significant impact on surface water quality.

The baseline concentrations for iron and manganese regionally are higher than the EQS values used for the initial screen. The BGS reports [9] that the glacial till overlying the bedrock has resulted in reducing conditions. As the presence of iron and manganese in groundwater is the result of natural processes acting on the geology, rather than anthropogenic contamination, these contaminants have been discounted from DQRA.

The quality of groundwater within the Chester Pebble Beds is generally good, and concentrations of some contaminants are lower than the published regional baseline. The exception to this is for ammoniacal nitrogen, where the background concentration in upgradient groundwater is 7.2mg/l compared to the reported baseline of 0.4mg/l. This suggests that there is an upgradient source of ammoniacal nitrogen in the Chester Pebble Beds that is affecting the quality of groundwater moving on to the site. There are landfill sites to the north-east (especially Queens Road landfill) which could be a source of ammoniacal nitrogen in groundwater entering the site. Also, the former gasworks is present over the Collyhurst Formation; ammoniacal nitrogen can be associated with old gasworks sites therefore it cannot be ruled out as a potential contaminant of concern.

River Irk water quality

Water quality in the River Irk was measured on four separate occasions as part of the ground investigations: in May 2021 and on three occasions in March 2022 at a point upstream of the site, in the centre of the site and downstream. A summary of the concentrations of contaminants of concern in the River Irk are presented in **Table 5**.

The concentrations of the contaminants of concern do not vary greatly from upstream of the site to downstream, indicating that the site is not having a significant impact on surface water quality.

Table 4 BGS baseline concentrations/background quality in sandstone

Contaminant	WQS Value (mg/l)	Background concentrations (mg/l)		Average concentrations within site groundwater (mg/l)		
		BGS baselinequality 95 th %ile	Upgradient groundwater quality in Chester Pebble Beds 95 th %ile	Shallow aquifer	Collyhurst Sandstone	Chester Pebble Beds
Cadmium	0.00015	0.005	0.00003	0.001	0.0002	0.0007
Chromium	0.0047	0.0057	0.0003	0.031	<WQS	0.008
Copper	0.03375	0.028	0.003	0.039	0.014	0.017
Iron	1	2.488	1.1	4.28	<WQS	0.99
Lead	0.00958	0.0024	0.0002	0.15	0.025	0.16
Manganese	0.226	2.41	0.84	3.34	1.08	0.72
Nickel	0.01607	0.0153	0.002	0.16	0.006	0.007
Zinc	0.03728	0.1115	0.004	0.16	0.05	0.16
Ammoniacal nitrogen as N	0.6	0.4	7.2	4.79	2.63	1.36
Aliphatic C8-10	0.3	N/A	<0.0001	1.09	<WQS	<WQS
Aliphatic C10-12	0.3	N/A	<0.001	1.94	<WQS	<WQS
Aliphatic C12-16	0.3	N/A	<0.001	4.19	0.9	<WQS
Aromatic C8-10	0.3	N/A	<0.0001	0.47	<WQS	<WQS
Aromatic C10-12	0.09	N/A	<0.001	1.12	0.03	<WQS
Aromatic C12-16	0.09	N/A	<0.001	2.5	0.36	<WQS
Aromatic C16-21	0.09	N/A	<0.001	1.5	<WQS	<WQS
Aromatic C21-35	0.09	N/A	<0.001	0.65	<WQS	<WQS
Fluoranthene	0.000006	N/A	0.00002	0.003	0.0002	0.0002
Anthracene	0.0001	N/A	<0.00001	0.0007	0.00004	<WQS
Benzo(a)pyrene	1.7E-07	N/A	<0.00001	0.0035	0.00014	0.00014

Table 5 Summary statistics for concentrations of contaminants of concern in the River Irk

Contaminant of Concern	WQS mg/l	River water quality		
		Upstream 95th %ile mg/l	Central 95th %ile mg/l	Downstream 95th %ile mg/l
Arsenic	0.01	0.003	0.003	0.003
Cadmium	0.00015	<0.0002	<0.0002	<0.0002
Chromium	0.0047	<0.001	<0.001	0.001
Copper	0.03375	0.00785	0.0069	0.0105
Iron	1	0.27	No data	0.3
Lead	0.00958	0.00285	0.0028	0.00895
Selenium	0.01	0.001	<0.001	0.001
Manganese	0.226	0.0946	0.0838	0.003
Nickel	0.01607	0.004	0.0039	0.004
Zinc	0.03728	0.05	0.0542	0.079
Ammoniacal Nitrogen	0.6	0.36	0.168	0.284
Fluoranthene	0.000006	0.00002	0.00002	0.00002
Anthracene	0.0001	0.00002	<0.00001	0.00002
Benzo(a)Pyrene	0.000017	<0.00001	<0.00001	<0.00001
TPH – Aliphatic C8-C10	0.3	<0.05	<0.05	<0.05
TPH – Aliphatic C10-C12	0.3	<0.05	<0.05	<0.05
TPH – Aliphatic C12-C16	0.3	<0.05	<0.05	<0.05
TPH – Aromatic C8-C10	0.3	<0.05	<0.05	<0.05
TPH – Aromatic C10-C12	0.09	<0.05	<0.05	<0.05
TPH – Aromatic C12-C16	0.09	<0.05	<0.05	<0.05
TPH – Aromatic C16-C21	0.09	<0.05	<0.05	0.0458
TPH – Aromatic C21-C35	0.09	<0.1	<0.1	0.1

5. DQRA Assessment

5.1 Methodology

The screening assessment has identified the following contaminants of concern for DQRA:

- Chromium
- Copper
- Lead
- Nickel
- Zinc
- Ammoniacal nitrogen as N
- TPH – Aliphatic fractions C8-C16, aromatic fractions C8-C35
- PAH (fluoranthene, anthracene, benzo(a)pyrene)
- Ammoniacal nitrogen

DQRA has been completed using the Environment Agency’s remedial targets methodology (RTM) and supporting worksheet to evaluate the contaminants listed above. “Remedial Targets” are derived at each level; these become increasingly less conservative as subsequent levels of assessment introduce new and more complex calculations to predict attenuation of contaminants.

The three levels of assessment include the following:

- Level 1 assesses the partitioning of a contaminant from the solid phase into the aqueous phase and compares calculated contaminant concentrations in ‘pore water’ to the target concentration;
- Level 2 considers dilution by the receiving groundwater and whether this is sufficient to reduce contaminant concentrations to acceptable levels;
- Level 3 considers whether natural attenuation (including dispersion, retardation and degradation) of the contaminant as it moves through the unsaturated and saturated zones to the receptor is sufficient to reduce contaminant concentrations to acceptable levels.

The input parameters used in the RTM models are provided in **Appendix B**. As discussed previously, the modelled scenarios are described below.

5.1.1 Remediation criteria for gasworks area

The gasworks is located over the Collyhurst Sandstone Principal Aquifer. Hydrocarbons have been noted in the made ground during the ground investigation. The DQRA is to consider the soil source in the gasworks area to derive remedial targets that are protective of groundwater. Contaminants of concern that have been modelled for the gasworks include selected TPH fractions, PAH and ammoniacal nitrogen as N, which are all detected in groundwater and are associated with gasworks operations.

5.1.2 Reuse criteria for site-won soils in St. Catherine’s Wood and Red Bank Terrace

Re-use criteria have been derived for site-won soils placed within St. Catherine’s Wood or Red Bank Terrace. As discussed in previous sections, this is because these areas are in close proximity to the river, and where soils are excavated from another part of the site (for example, Red Bank Plateau) it is considered prudent to ensure that such materials will not pose an unacceptable risk to the River Irk.

Two sets of re-use criteria (Zone 1 and Zone 2) have been generated for fill derived elsewhere within the HIF Infrastructure site that is placed within St. Catherine’s Wood or Red Bank Terrace, depending on the distance from the river in which the soils are to be re-used. The zones are shown in **Drawing 9**.

These re-use criteria are designed to be protective of controlled waters, assuming that contaminants are the metals, TPH and PAH fractions identified in the initial screen of the data.

Re-use criteria will not be derived for materials that are excavated within Red Bank Plateau and recovered for re-use within the Plateau area. In addition, re-use criteria will not be derived for material within St Catherine’s Wood and Red Bank Terrace that is to be locally redistributed during regrading works. However, if material from any source within the site is placed within Zone 1 shown on **Drawing 9**, it will be screened against the relevant set of re-use criteria.

5.2 DQRA outcome – gasworks

5.2.1 RTM output

The calculated soil remedial targets for the gasworks area are provided in **Appendix B**. The target concentrations have been calculated for soil and soil leachate. The remedial targets are summarised in **Table 6** below against the 95th %ile soil concentrations detected during the ground investigations within the gasworks.

It should be noted that visible evidence of hydrocarbon contamination was identified on perched groundwater (a sheen) and in soil within the gasworks area, and the values below do not account for NAPL within perched waters. Measures to remove NAPL from perched groundwater will be addressed in the Remediation Strategy.

Table 6 Summary of remediation targets for gasworks area

Contaminant	RTM-calculated soil remediation target (mg/kg)	95 th %ile of soil concentration in gasworks (mg/kg)	95 th %ile of soil concentration on plateau (mg/kg)	RTM-calculated leachate target (mg/l)
Ammoniacal nitrogen	4.5	Not tested in soil	Not tested in soil	8.7
Benzo(a)Pyrene	3.6	32.8	2.5	0.0005
Fluoranthene	0.3	49.2	7	0.0003
Anthracene	0.9	16	1.8	0.003
TPH – Aliphatic C8-C10	4860	27.4	9.9	2.6
TPH – Aliphatic C10-C12	37900	52.3	9.9	2.6
TPH – Aliphatic C12-C16	758000	211	17.9	2.6
TPH – Aromatic C8-C10	1340	88	7.9	14.4
TPH – Aromatic C10-C12	772	85.4	31.2	5.3
TPH – Aromatic C12-C16	3860	546	60.4	13.3
TPH – Aromatic C16-C21	1120	1242	85	1.2
TPH – Aromatic C21-C35	8100	2989	200	1.1
TPH – C8-C35	2500*#			
* RTM-calculated remediation criteria for several of the TPH fractions are far in exceedance of any soil concentrations. Any soils exceeding these criteria would be visibly grossly contaminated. Therefore, it was considered appropriate to set a soil remediation target for TPH C8-C35.				

Contaminant	RTM-calculated soil remediation target (mg/kg)	95 th %ile of soil concentration in gasworks (mg/kg)	95 th %ile of soil concentration on plateau (mg/kg)	RTM-calculated leachate target (mg/l)
# If exceedances of these values are noted, the risk-derived criteria for individual carbon bands detailed in this table shall be applied.				

5.2.2 Discussion of remediation criteria

The validity of the RTM-calculated remediation criteria in the context of the site is discussed below.

RTM-calculated remediation criteria for several of the TPH fractions are extremely high and far in exceedance of any site soil concentrations recorded. Any soils exceeding these criteria would be visibly grossly contaminated and therefore require remediation in accordance with the discovery strategy. Therefore, a soil remediation target for TPH C8-C35 of 2500mg/kg has been set for soil within the gasworks area. Within this, individual hydrocarbon fractions will still be screened, but the overall target of 2500mg/kg is considered appropriate to protect controlled waters, together with the implementation of a discovery strategy to ensure than no free phase hydrocarbons are missed.

The soil targets generated by the DQRA for the gasworks are extremely low for some of the contaminants of concern, particularly the PAH compounds, and may not be achievable considering the typical soil concentrations observed during the ground investigations. The main reasons for these low RTM-calculated remedial targets is the very low water quality standards used in the modelling, and conservatism of the modelling e.g. the short travel distance to the receptor (see **Appendix B**).

The 95%ile concentration for the PAH compounds within the made ground on Red Bank Plateau is provided in **Table 6** to put the calculated soil targets into context. The RTM-calculated targets for the PAH compounds Fluoranthene and Anthracene are inappropriate as remediation criteria, as they would require the remediation objective to be to remediate the soil within the gasworks area of the HIF Infrastructure site to levels lower than the remainder of the Plateau. This is clearly not a sustainable approach and would not achieve the carbon targets for the scheme as it would involve the removal of substantial quantities of made ground.

The 95th percentile values for the Red Bank Plateau show that the 95th %ile soil concentrations for PAHs in the gasworks are not typical of Red Bank Plateau generally and remediation to reduce soil concentrations to these levels would remove contamination outliers and bring the soil quality into line with the remainder of the Plateau.

The remediation of the gasworks area will remove the source of the gasworks contamination, which may currently be affecting groundwater quality local to the gasworks area. Minimal infiltration is expected to occur through the gasworks area post-development as it will be largely covered with buildings and hardstanding, with a surface water drainage system. It is therefore proposed that the soil remedial targets used for the gasworks area are adjusted to match the 95th %ile concentration of the Red Bank Plateau area for PAHs, presented in **Section 7.2** below.

5.3 DQRA outcome – re-use of fill materials within St. Catherine’s Wood or Red Bank Terrace

Current earthworks proposals (**Drawing 8**) indicate that a relatively small quantity of material excavated from Red Bank Plateau will need to be transferred to each of the areas of proposed earthworks in St Catherine’s Wood and Red Bank Terrace areas of the site. The materials transferred to these areas of the site will need to be screened against the criteria set out in **Table 7** and **Table 8**, depending on proximity of the placed material to the River Irk. The St. Catherine’s Wood and Red Bank Terrace areas have been divided into two zones for the purposes of generating re-use criteria, as shown in **Drawing 9**.

5.3.1 RTM output

The RTM-calculated remedial targets for the re-use of fill within St. Catherine’s Wood and Red Bank Terrace are provided in **Appendix B**. The target concentrations have been calculated for soil and soil leachate. The remedial targets for Zone 1 are summarised in Table 7 and those for Zone 2 are in **Table 8**.

It should be noted that soil containing visible evidence of hydrocarbon contamination will not be suitable for re-use. This will need to be addressed in the Remediation Strategy.

Table 7 Calculated re-use criteria for site-won soils placed within Zone 1

Contaminant	RTM-calculated soil remediation target (mg/kg)	95 th %ile of soil concentration within site (mg/kg)	RTM-calculated leachate target (mg/l)
Chromium	93.5	38	0.02
Copper	48	300	0.1
Lead	12.9	868	0.01
Nickel	26.5	48.9	0.05
Zinc	191	646	0.4
Benzo(a)Pyrene	0.4	5	0.00006
Fluoranthene	0.04	12	0.00003
Anthracene	0.15	3.2	0.0005
TPH – Aliphatic C8-C10	1910	11	1.03
TPH – Aliphatic C10-C12	14900	17	1.03
TPH – Aliphatic C12-C16	297000	39	1.03
TPH – Aromatic C8-C10	153	10	1.64
TPH – Aromatic C10-C12	76	29	0.53
TPH – Aromatic C12-C16	208	92	0.72
TPH – Aromatic C16-C21	323	68	0.35
TPH – Aromatic C21-C35	2450	233	0.34
TPH C8-C35	2500*#		
* RTM-calculated remediation criteria for several of the TPH fractions are far in exceedance of any soil concentrations. Any soils exceeding these criteria would be visibly grossly contaminated. Therefore, it was considered appropriate to set a soil remediation target for TPH C8-C35. # If exceedances of these values are noted, the risk-derived criteria for individual carbon bands detailed in this table shall be applied.			

Table 8 Calculated of re-use criteria for site-won soils placed within Zone 2

Contaminant	RTM-calculated soil remediation target (mg/kg)	95 th %ile of soil concentration within site (mg/kg)	RTM-calculated leachate target (mg/l)
Chromium	94	38	0.02
Copper	51	300	0.1
Lead	14	868	0.014
Nickel	28	48.9	0.06
Zinc	191	646	0.4
Benzo(a)Pyrene	1.4	5	0.0002
Fluoranthene	0.11	12	0.0001

Contaminant	RTM-calculated soil remediation target (mg/kg)	95 th %ile of soil concentration within site (mg/kg)	RTM-calculated leachate target (mg/l)
Anthracene	0.34	3.2	0.001
TPH – Aliphatic C8-C10	2010	11	1.1
TPH – Aliphatic C10-C12	14900	17	1
TPH – Aliphatic C12-C16	313000	39	1.1
TPH – Aromatic C8-C10	470	10	5.1
TPH – Aromatic C10-C12	265	29	1.8
TPH – Aromatic C12-C16	1260	92	4.3
TPH – Aromatic C16-C21	449	68	0.5
TPH – Aromatic C21-C35	3280	233	0.4
TOH – C8-C35	2500*#		
* RTM-calculated remediation criteria for several of the TPH fractions are far in exceedance of any soil concentrations. Any soils exceeding these criteria would be visibly grossly contaminated. Therefore, it was considered appropriate to set a soil remediation target for TPH C8-C35.			
# If exceedances of these values are noted, the risk-derived criteria for individual carbon bands detailed in this table shall be applied.			

5.3.2 Discussion of re-use criteria

RTM-calculated remediation criteria for TPH Aliphatic C10-C12 and Aliphatic C12-C16 are extremely high and far in exceedance of any site soil concentrations recorded. Any soils exceeding these criteria would be visibly grossly contaminated and therefore would not be suitable for re-use in accordance with the remediation strategy. Therefore, a soil remediation target for TPH C8-C35 of 2500mg/kg has been set. Within this, individual hydrocarbon fractions will still be screened, but the overall target of 2500mg/kg is considered appropriate, together with the implementation of a discovery strategy to ensure than no free phase hydrocarbons are missed.

The RTM-calculated criteria for re-use of excavated materials (see cut and fill plan, **Drawing 8**) are extremely low for some of the contaminants of concern, particularly the PAH compounds, copper and lead, and may not be achievable based on the typical soil concentrations observed during the ground investigations. The main reasons for these low RTM-calculated remedial targets are the very low water quality standard used in the modelling and conservatism inherent in the modelling (see **Appendix B**). The upper 95th %ile concentrations in soil from across the HIF Infrastructure site are also presented in **Table 7** and **Table 8** to provide some context to the soil targets generated in RTM.

An additional useful comparator is the published normal background concentration (NBCs) [24] for benzo(a)pyrene in soil in urban areas is 3.6mg/kg, for copper it is 190mg/kg, and for lead 820mg/kg, all of which are significantly higher than the calculated targets. It is proposed that the re-use criteria used in St. Catherine’s Wood and Red Bank Terrace are adjusted to match the normal background concentrations where these are higher than the RTM-calculated criteria. In addition, the re-use criteria for Anthracene and Fluoranthene will match the 95%ile concentrations for the made ground within the Red Bank Plateau (see **Section 7.2** below). This will ensure that the risk of harm to controlled waters will not exceed the current situation.

6. Uncertainty assessment

All contaminant risk assessment modelling assesses a simplified representation of ground conditions. The RTM worksheet is a deterministic fate and transport model that uses single parameter inputs to quantify potential migration and attenuation. Like any natural system the ground conditions and hydrogeological characteristics at the HIF Infrastructure site vary spatially and temporally and it is not possible for the modelling approach to account for all of the natural variation. The aim instead is to capture typical conditions and where uncertainty or variation exists to complete a reasonable worst-case evaluation of contaminant transport. Several specific methods have been used to help understand potential uncertainty and to support the parameter selection approach:

- The modelling is supported using site data where possible. This includes the definition of contaminant source areas, the use of geotechnical testing to understand the physical properties of specific strata and hydrogeological review of groundwater level data to better understand potential groundwater flow characteristics.
- A conservative modelling approach has been undertaken. Where site data is unavailable or limited or where uncertainty is high, the parameter and model selections have been conservative.
- The model assumes the biodegradation of contaminants, based on measurements of the dissolved oxygen concentrations in groundwater within the two sandstone aquifers which suggest an aerobic environment where degradation may be occurring. Published values have been used to estimate the half-lives of contaminants in water beneath the site.
- Model calibration and output sense checking has been undertaken.

7. Summary and recommendations

7.1 Summary of risk assessment findings

The assessments presented in this report are intended to inform the Remediation Strategy for the Victoria North HIF Infrastructure works. Assessment of the groundwater data has confirmed the presence of contamination in both the shallow and deep aquifers, which is likely to be the result of historical industrial uses both within and surrounding the Site and the placement of significant quantities of made ground to form Red Bank Plateau.

Despite the presence of contamination in the aquifers, and the hydrogeological review indicating that these aquifers discharge into the River Irk, the quality of water within the River Irk is good and does not deteriorate as it passes the site.

Areas of visible hydrocarbon contamination have been noted during the ground investigations within the site, which may be affecting the quality of controlled waters (groundwater) locally. Remedial targets have been generated for the former gasworks area shown in **Drawing 4**, which was identified as a potential source area of contamination affecting groundwater quality.

Another area of contamination, within the footprint of a former railway carriage shed (shown in **Drawing 5**), is not considered to be posing an unacceptable risk to controlled waters. However, remediation of that area to remove grossly contaminated soils and validate excavations will be required by the Remediation Strategy.

The laterally extensive and very thick made ground is considered likely to be contributing to the overall impacted groundwater quality within the site area. To ensure that the re-use of excavated materials does not increase the risk to controlled waters above that which is already present, soils that are excavated from one of the three main areas of the site (**Figure 2**) and used as fill in another, will be screened against the re-use criteria presented in this DQRA. Two sets of re-use criteria have been generated depending on the distance from the river in which filling is to be undertaken. The re-use criteria proposed in this DQRA will not be applied to materials that are re-used as fill in the area from which they were excavated.

Although it is unlikely that regrading works will involve the relocation of soils from one zone to another, any soils relocated into Zone 1 adjacent to the river (**Drawing 9**), will also need to comply with the relevant re-use criteria.

These re-use criteria will need to be incorporated into the Earthworks Specification for the HIF Infrastructure works and the Remediation Strategy for the enabling works (based on the outcome of this DQRA).

This risk assessment will also inform the design of follow-on development by future plot developers, to ensure compliance with the assumptions in this report.

7.2 Recommendations for remediation strategy

A Remediation Strategy and Verification Plan is to be developed for the HIF Infrastructure works by BAM, informed by the outcome of this controlled waters risk assessment. Approval of the Remediation Strategy and Verification Plan is anticipated to be a pre-commencement planning condition. The following actions need to be carried forward into that document:

- Gross hydrocarbon contamination should be removed from where encountered within the site, including from the former carriage shed area and the excavation verified. Gross contamination is defined as material saturated with free product, i.e. significant visible oil, solvents or tar within soil, or on/within groundwater;
- Remediation is required within the former ‘gasworks’ area, including excavation of subsurface structures and associated contamination. The remedial targets to be met are set out in **Table 9** below. The Remediation Strategy should include frequency of testing and approach to data interpretation;
- During works to re-naturalise the river banks through St Catherine’s Wood, inspections should be undertaken to identify visual or olfactory evidence of the discharge of contaminants into the river through high permeability material associated with the former river meander bend, or from the face of the regraded river banks. If either of these are encountered, consideration should be given to the adoption of measures to address these potential

contaminant linkages (for example, the provision of low permeability material at appropriate locations along the river banks);

- Materials sourced from elsewhere within the site that are re-used within St. Catherine’s Wood and Red Bank Terrace should be tested to ensure they achieve the proposed materials re-use criteria, as set out in **Table 10** and **Table 11** below, which have been determined on the basis of the distance from the banks of the River Irk in which fill is to be placed. The Remediation Strategy should include frequency of testing and approach to data interpretation;
- Implementation of a discovery strategy during remediation to ensure that any previously unforeseen areas of contamination are identified and dealt with and are not taken for re-use as fill elsewhere within the site. In addition, any historic water wells that are encountered during the discovery strategy should be grouted to prevent them acting as a pathway in future.

Table 9 Proposed soil remedial targets for gasworks area

Contaminant	Soil target (mg/kg)	Soil leachate target (mg/l)	Rationale for soil target
Ammoniacal nitrogen	4.5	8.7	RTM
Benzo(a)Pyrene	3.6	0.0005	RTM
Fluoranthene	7	0.0003	95%ile of Plateau made ground (soil), RTM (leachate)
Anthracene	1.8	0.003	95%ile of Plateau made ground (soil), RTM (leachate)
TPH – Aliphatic C8-C10	4860*	2.6	RTM
TPH – Aliphatic C10-C12	37900*	2.6	RTM
TPH – Aliphatic C12-C16	758000*	2.6	RTM
TPH – Aromatic C8-C10	1340*	14.4	RTM
TPH – Aromatic C10-C12	772*	5.3	RTM
TPH – Aromatic C12-C16	3860*	13.3	RTM
TPH – Aromatic C16-C21	1120*	1.2	RTM
TPH – Aromatic C21-C35	8100*	1.1	RTM
TPH – C8-C35	2500*#	-	Professional judgment
*Discovery strategy to be implemented to ensure no soil with visual or olfactory evidence of contamination is re-used			
# If exceedances of these values are noted, the risk-derived criteria for individual carbon bands detailed in this table shall be applied.			

Table 10 Proposed re-use criteria for site-won soils placed within Zone 1

Contaminant	Soil target (mg/kg)	Leachate target (mg/l)	Rationale for soil target
Chromium	93.5	0.02	RTM
Copper	190	0.1	NBC (soil), RTM (leachate)
Lead	820	0.01	NBC (soil), RTM (leachate)
Nickel	26.5	0.05	RTM
Zinc	191	0.4	RTM

Contaminant	Soil target (mg/kg)	Leachate target (mg/l)	Rationale for soil target
Benzo(a)Pyrene	3.6	0.00006	NBC (soil), RTM (leachate)
Fluoranthene	7	0.00003	95%ile (soil), RTM (leachate)
Anthracene	1.8	0.0005	95%ile (soil), RTM (leachate)
TPH – Aliphatic C8-C10	1910*	1	RTM
TPH – Aliphatic C10-C12	14900*	1	RTM
TPH – Aliphatic C12-C16	297000*	1	RTM
TPH – Aromatic C8-C10	153*	1.6	RTM
TPH – Aromatic C10-C12	76*	0.5	RTM
TPH – Aromatic C12-C16	208*	0.7	RTM
TPH – Aromatic C16-C21	323*	0.4	RTM
TPH – Aromatic C21-C35	2450*	0.3	RTM
TPH C8-C35	2500*#	-	Professional judgement
*Discovery strategy to be implemented to ensure no soil with visual or olfactory evidence of contamination is re-used			
# If exceedances of these values are noted, the risk-derived criteria for individual carbon bands detailed in this table shall be applied.			

Table 11 Proposed re-use criteria for site-won soils placed within Zone 2

Contaminant	Soil target (mg/kg)	Leachate target (mg/l)	Rationale for soil target
Chromium	94	0.02	RTM
Copper	190	0.1	NBC (soil), RTM (leachate)
Lead	820	0.014	NBC (soil), RTM (leachate)
Nickel	28	0.06	RTM
Zinc	191	0.4	RTM
Benzo(a)Pyrene	3.6	0.0002	NBC (soil), RTM (leachate)
Fluoranthene	7	0.0001	95%ile (soil), RTM (leachate)
Anthracene	1.8	0.001	95%ile (soil), RTM (leachate)
TPH – Aliphatic C8-C10	2010*	1	RTM
TPH – Aliphatic C10-C12	14900*	1	RTM
TPH – Aliphatic C12-C16	314000*	1	RTM
TPH – Aromatic C8-C10	470*	5	RTM
TPH – Aromatic C10-C12	265*	1.8	RTM
TPH – Aromatic C12-C16	1260*	4.3	RTM
TPH – Aromatic C16-C21	449*	0.5	RTM
TPH – Aromatic C21-C35	3280*	0.4	RTM
TPH C8-C35	2500*#	-	Professional judgement
*Discovery strategy to be implemented to ensure no soil with visual or olfactory evidence of contamination is re-used			
# If exceedances of these values are noted, the risk-derived criteria for individual carbon bands detailed in this table shall be applied.			

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Drawings

Drawing 1	Cross section through gasworks/St. Catherine’s Wood area
Drawing 2	Cross section through Red Bank Terrace area
Drawing 3	Bedrock types within site
Drawing 4	Outline of gasworks area
Drawing 5	Historical site features
Drawing 6	Inferred contours of shallow groundwater
Drawing 7	Deep groundwater levels
Drawing 8	Proposed cut and fill areas
Drawing 9	Site zoning for fill materials close to river

Appendix A

Environment Agency comments on GIR

Our ref: SO/2021/121237/05-L01

Your ref: MCC Victoria North SLA

Date: 04 February 2022

FAO: Victoria North Infrastructure Team / Arup Infrastructure Team / Colin Reader

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ENV6004932R Manchester City Council / EA Victoria North Service Level Agreement (SLA)

**Victoria North infrastructure Works Package - SLA Item: FT-JAN-7/ FT-FEB-9
Draft Interpretative Ground Investigation Report Review**

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Dear Victoria North Infrastructure Project Team / Mr Reader,

Thank you for requesting written review, by the Environment Agency (EA), of the draft Ground Investigation Interpretative Report (GIR) detailed below:

- Victoria North (VN) Infrastructure Works – Ground Investigation Interpretative Report. Report Reference: VNIF-ARP-ZZ-YYY—RP-CG-0008. Draft P01. Prepared by Arup on behalf of Manchester City Council. Dated: 22nd December 2021.

The GIR report was initially received by the Environment Agency (EA), via electronic transfer, on Tuesday 11th January 2022.

EA GIR Review Purpose / Understanding / Context / Limitations

EA Review Purpose

Further to discussion held with the VN Infrastructure Project Management Team, we understand the intended purpose of this written review of the draft GIR report is provide opportunity to identify and draw attention to any key concerns or constraints the EA may have, with regards to matters relating to the protection of controlled waters, and in turn offer advice and guidance to the VN project team / Arup on these aspects; with the intended outcome of this reviewing being greater assurance and confidence that submission(s) made as part of planned forthcoming planning application for the Infrastructure Enabling Works Package (commonly referred to as 'Application 2') (and subsequent submissions) will of a quality which accords with the requirements of the National Planning Policy Framework (NPPF).

EA Understanding

As detailed within the draft GI, we understand that it the intention of the VN HIF Project Team to limit the future works which will be progressed as part of 'Application 2' to ensuring that land with the defined area for this application is suitable for the current intended masterplan end-uses and that any unacceptable risks to groundwater or surface waters will be addressed, reserving all other matters (e.g. alternation of intended final plot-use) for future developers.

Environment Agency
Richard Fairclough House Knutsford Road, Warrington, WA4 1HT.
Customer services line: 03708 506 506
www.gov.uk/environment-agency

Cont/d..

Further to above, we are also aware not all of the land reported on within the Draft GIR will be included as a part of the subsequent remedial work anticipated as part of the delivery of 'application 2'. Specifically, we understand, further to previous engagements with the VN HIF Contaminated Land Team (pre-end of RIBA Stage 3), that the 'Travis Island' (RB16, RB17), 'New Town' Neighbourhood (NT02, NT03 and NT04) and several of the Red Bank Viaduct development plots (understood to be RB08, RB11 and RB12a) have now been omitted from scope of any further remedial work to be undertaken as part of this application.

Limitations of EA Review

Finally, we have reviewed the report in the knowledge that the version presented to the EA is not the final report and will understandably be subject to further additional editing. Consequently, we would advise the reader that there may limitation to the EA commentary provided below as report does not presently include the usual standard appendices seen as part of formal planning submissions e.g. borehole logs, laboratory data sheets/tabulated data and other geo-environmental and geo-technical information.

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In accordance with the above, please see below commentary and review of the draft GIR which has been provided by EA's Greater Manchester Contaminated Land Specialist Lee Beveridge.

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EA Contaminated Land Specialist Commentary- VNIF-ARP-ZZ-YYY—RP-CG-0008. Draft P01

Site Overview

From our earlier review of the 2019 Phase 1 Ground Investigation Report (MNG-ARP-SW-RP-CG-102) prepared by Arup for the site, we are aware that the VN site has a former industrial history in that the current ground levels has been artificial created by use of made ground; the wider area has been formerly railway land and that in the north-eastern part of the site was a small-scale gas works.

Industrial land use of the site continued for over 100 years until consolidation of the railway system led to the decommissioning of the raised railway spur into Manchester Victoria Station and the removal of rail infrastructure and sidings; including the small-scale gas works in the north-eastern corner of the site.

From 1989 onwards the St. Catherine's Wood area, the Red Bank Plateau and the elevated Red Bank Viaduct have become derelict with the plateau and wood areas being heavily overgrown.

Associated with the extended period of industrial land use detailed above is the heavily modified landform and River Irk corridor. The understand from the draft GIR and previous submission(s) is that the original course of the River Irk has modified and that previously cut channels which created mill-races have been subsequently infilled with imported materials. The main river channel is now heavily modified and canalised with vertical man-made walls flanking both the right-hand and left-hand banks for the full extent of development area in question.

Environmental

We understand that the site is in a reasonably, environmentally, sensitive location with the wider parcel of land located immediately adjacent to the River Irk and above a Principal, Secondary A and Secondary B Aquifer. We consider these waterbodies to be Controlled Waters and therefore valid environmental receptors. Records show that the site is not within a Source Protection Zone.

Whilst not recorded or permitted, the types of industries which have been present (Gasworks, Chemical and Dye Works and Iron Works) may have been historically associated with groundwater abstraction points. It is possible, these abstraction boreholes (if existent) may not have been adequately decommissioned and could still be present therefore presenting a preferential contaminant linkage to the underlying bedrock aquifers. We recommend that relevant records are consulted to assess this possibility of this.

Ground Investigation (to date)

We understand that the site has been subject to at least two grounds of ground investigation and that intrusive investigations across the site have been undertaken to allow of environmental samples to be taken, analysed, and interpreted against.

One phase of ground investigation collected information on general site wide conditions whilst the most recent investigation targeted known historic features which were likely sources of contamination.

Supporting the above phases of investigation are limited phases of ground and surface water sampling of the ground waters and river.

Assessment

Having considered the information which has been provided, in the context that the report has been developed for (i.e. the limited works under HIF); the tabulated information identifies that the former industrial land uses have introduced elevated concentrations of contamination in the locations investigated which are likely to have adversely impacted controlled water receptors.

In the context of the primary receptors acting as pathways; these could adversely impact other receptors (e.g., impacted shallow groundwaters migrating and impacting upon other groundwater and surface water receptors) especially with the development proposal to alter the landform for development and public realm purposes and removed hard, in ground barriers (i.e. river walls) to re-establish potential contaminant linkages.

St. Catherine's Wood

This area is chiefly associated with the steep sloped flanks of the Red Bank Plateau but also includes the area to the north where the plateau once supported the former gas works site.

We acknowledge and accept that the current vegetation cover and slopes does preclude a good deal of ground investigation but by the same degree this means that the area has the least number of intrusive investigation points and therefore adverse contamination may be present.

In terms of the former gas works area there is clear evidence from the ground investigation and tabulated sample results that these works have had an adverse impact that is sufficiently impacting the water environment as to be a cause of concern for the EA to for us to recommend that assessment of risk, the creation of suitable remedial target concentrations and the need for land remediation of what we suspect to be gas works waste.

Given the composition of the ground beneath the gas works site; made ground with a predominance of granular made ground (Fig7) then there is a likelihood of vertical and lateral contamination migration and the presence of additional underground features which may yet to be identified (i.e. tar liquor wells and tanks).

We also note, at this location, parts of the site are situated above the older mill race channel. We raise the question as to where this secondary feature may act as a pathway for migration of mobile contamination to elsewhere on the site; a matter we believe that will require additional assessment (and potentially sampling).

Finally, we note the final design brief will result in alteration to the topography of the St Catherine's Wood area as part of the creation of an improved public realm in connectivity with the waterfront. For this newly created access and alteration of topology, it will be important to further investigate and understand groundwater conditions so that the intended removal of the current riverbank wall will not inadvertently result in the creation a contaminant linkage-pathway and as consequence degradation of the River Irk. This approach will also be needed to ensure that any materials imported to this area in the future as a part of the public realm work is geo-chemically acceptable given its proximity to the watercourse.

We would remind the VN project team without full characterisation of ground conditions, that it will not be possible for the EA to recommend to the planning authority (as part of pre-commencement condition discharge) the commencement of development as we would need to ensure accordance with Regulation 33 of the [The Water Environment \(Water Framework Directive\) \(England and Wales\) Regulations 2017](#) and 174 of the National Planning Policy Framework NPPF.

We would also note, as part of the above, the potential possibility that the further investigations may in turn mean that remedial requirements prohibit the presently understood intention to retain semi-natural woodland habitat within the public realm area and that careful consideration as to the implications of this possibility upon the project is given by the VN design and management teams given the intention o achieve an overall 10% Biodiversity Net Gain (BNG) as part of the overall project.

Red Bank Plateau

The GIR report that identifies this area to part of the former railway sidings and main rail line into Manchester Victoria station.

As part of this review, we have looked at third-party historic images of the railway land dating back to the mid and later 1980's to understand the overlay layout of the sidings area, which has helped us quantify the site and put into perspective the overall layout of the land based on its current condition.

The ground investigations undertaken for this area are more comprehensive and detailed and have identified that the former railway has introduced some low levels of

contamination to the made ground levels but there is more significant contamination in the vicinity of the former carriage shed and the two basal infilled waterbody areas (drawing -04).

Having reviewed the tabulated information, we are satisfied that these areas will need further assessment and possible sampling. We are concerned regarding the condition of the made ground beneath the former carriage shed and believe that this area will need remediation under the terms of this phase of development.

Red Bank Viaduct

Using our previous review of the earlier 2019 Phase 1 Ground Investigation Report (MNG-ARP-SW-RP-CG-102) prepared by Arup for the site for the wider development area, we are aware that this area has been previously used for heavier industrial activities which have included Dye /Chemical works, Glue Works, Iron works and a fireproofing plating works.

The GIR report suggests that the majority of the Red Bank Viaduct development area falls outside of the HIF phase of works, which is likely to account for the lower number of intrusive investigation points and the limited number of groundwater sampling points. Whilst we accept this approach and understand the drivers behind this decision the results which have been presented show that the former industrial land uses may have led to adverse concentration of contamination in the ground such that there could be a risk to water environment receptors.

Consequently, it will be important to understand condition further as we understand that soils movements, landscape reprofiling and public realm development is planned for this area. As such it will be critical to develop acceptable, receptor driven, reuse criteria that will be protective of the water environment. These values are likely to differ from the generic assessment criteria that the GIR report currently refers to and may be more stringent.

Overall

Having reviewed the report in its current draft version, we are satisfied that there does, from the information available, appear to be widespread significant contamination, that is likely to pose a significant risk to controlled waters.

However, as outlined above, there are specific areas where there appears to be increased concentrations of contamination which will, as highlighted above, require further assessment and consideration to ensure the site is suitable for its intended end-use (as defined within the masterplan), development aspirations can be realised, and that the site does not pose an unacceptable risk to controlled waters - according with relevant policy and good practice.

As detailed within the introduction to this letter, we would again draw attention to the fact that not all information associated with the draft GIR report has been presented to the EA and there is potential that this could alter our position regarding the additional investigation(s) which are required.

In any instance, it is possible to conclude confidently from our review of the GIR that remedial work (the extent of which cannot yet be defined) will be required and that further investigations will be needed to fully understand the scope of scale of this. We welcome the fact that this has also been recognised by the Arup within the GIR report.

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We trust that you will find the contents of this letter beneficial. However, as detailed within GIR we understand that Arup is presently in the process of preparing a specification of further ground investigation works to be undertaken. Consequently, further to the above written EA commentary, we would welcome the opportunity to further discuss with the VN project team the scope and details of further GI and/or any queries or questions they may have in relation to the above.

Yours sincerely

Mr Andy Davies
Sustainable Places Advisor

Direct e-mail andy.davies1@environment-agency.gov.uk

Appendix B

Detailed Quantitative Risk Assessment (DQRA)

Page 1 of 2

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Page 1 of 2

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_BH210	BH210	GEO_BH212	BH212	RE15	RE15
Sample Ref	200	100		100	1	
Easting	384479.67	384479.67	384487.32		384476.006	384476.006
Northing	399554.7	399554.7	399426.078		399396.975	399396.975
Hole Elevation (mOD)	40.45	40.45	30.377		30.168	30.168
Sample Depth (mbgl)	10.8	10.8	3.48		3.08	3.55
Piezometer top (mbgl)	14	14	5.5		5.5	5.5
Piezometer base (mbgl)	19.6	19.6	9		10	10
Sample Date	10/08/21	27/05/2021	05/07/22	01/06/2021	15/02/22	05/07/22
Investigation	NW 1604	NW 1604	NW 1604		River Works 2021/iver Works 2021/	River Works 2021/iver Works 2021/
Response zone	Chester Formation	Chester Formation	Chester Formation	Chester Formation	Chester Formation	Chester Formation

Contaminant Name	GAC	Source	Units	Total > LOD	Total > GAC	Average	Max
MCPA (w)	0.012	EQS*	mg/l	0 of 0	0	#DIV/0!	
MCPB (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
MCPP- (Mecoprop) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Picloram (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Triclopyr (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Bromacil (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Carbetamide (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorobutram (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Chloroprotham (w)	0.01	EQS*	mg/l	0 of 0	0	#DIV/0!	
Chlortoluron (w)	0.002	EQS*	mg/l	0 of 0	0	#DIV/0!	
Cyanazine (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Diuron (w)	0.0002	EQS	mg/l	0 of 0	0	#DIV/0!	
Isoproturon (w)	0.0003	EQS	mg/l	0 of 0	0	#DIV/0!	
Linuron (w)	0.0005	EQS	mg/l	0 of 0	0	#DIV/0!	
Monuron (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Primicarb (w)	0.001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Protham (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Cyfluthrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Cypermethrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Deltamethrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Fenvalerate (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Permethrin (w)	0.00001	EQS	mg/l	0 of 0	0	#DIV/0!	
Pesticides							
Aldrin (w)	0.00003	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorothalonil (w)	0.000035	EQS	mg/l	0 of 0	0	#DIV/0!	
Dichlorobnill (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Dieldrin (w)	0.00003	DWS	mg/l	0 of 0	0	#DIV/0!	
Endosulphan I (Alpha) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Endosulphan II (Beta) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Endosulphan Sulphate (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Endrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Heptachlor (w)	0	EQS	mg/l	0 of 0	0	#DIV/0!	
Heptachlor epoxide (w)	0.00003	DWS	mg/l	0 of 0	0	#DIV/0!	
Isodrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Pendimethalin (w)	0.000001	EQS	mg/l	0 of 0	0	#DIV/0!	
Permethrin II (trans) (w)	0.000001	EQS	mg/l	0 of 0	0	#DIV/0!	
Quintozene (PCNB) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Tecnazene (w)	0.001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Triadimefon (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Triallate (w)	0.00025	EQS*	mg/l	0 of 0	0	#DIV/0!	
Trifluralin (w)	0.00003	EQS	mg/l	0 of 0	0	#DIV/0!	
alpha-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
beta-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
cis-Chlordane (Alpha) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
delta-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
gamma-Hexachlorocyclohexane (HCH / Li	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
o,p-DDD (2,4) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
o,p-DDE (2,4) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
o,p-DDT (2,4) (w)	0.000025	EQS	mg/l	0 of 0	0	#DIV/0!	
o,p-Methoxychlor (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
p,p-DDE (4,4) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
p,p-DDT (4,4) (w)	0.00001	EQS	mg/l	0 of 0	0	#DIV/0!	
trans-Chlordane (Gamma) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Azinphos-ethyl (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Azinphos-methyl (w)	0.00001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Carbophenothion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorfenvinphos (w)	0.0001	EQS	mg/l	0 of 0	0	#DIV/0!	
Chlorpyrifos (w)	0.00003	EQS	mg/l	0 of 0	0	#DIV/0!	
Chlorpyrifos-methyl (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Cumaphos (w)	0.00003	EQS*	mg/l	0 of 0	0	#DIV/0!	
Diazinon (Dimpylate) (w)	0.00001	EQS	mg/l	0 of 0	0	#DIV/0!	
Dichlorvos (w)	0.000001	EQS	mg/l	0 of 0	0	#DIV/0!	
Dimethoate (w)	0.00048	EQS	mg/l	0 of 0	0	#DIV/0!	
Disulfoton (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Elthion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Fenitrothion (w)	0.00001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Fenthion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Malathion (w)	0.00001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Methyl Parathion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Mevinphos (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Parathion (Ethyl Parathion) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Phorate (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Phosalone (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Phosphos-methyl (w)	0.000015	EQS*	mg/l	0 of 0	0	#DIV/0!	
Propetamphos (w)	0.00003	EQS*	mg/l	0 of 0	0	#DIV/0!	
Triazophos (w)	0.000005	EQS*	mg/l	0 of 0	0	#DIV/0!	
Other							
2,3,4,6-Tetrachlorophenol			mg/l	No GAC	-	#DIV/0!	
2,3,5,6-Tetrachlorophenol			mg/l	No GAC	-	#DIV/0!	
2-Nitroaniline			mg/l	No GAC	-	#DIV/0!	
3+4-Methylphenol			mg/l	No GAC	-	<0.001	<0.001
3-Nitroaniline			mg/l	No GAC	-	#DIV/0!	
4-Chlorophenyl Phenyl Ether			mg/l	No GAC	-	#DIV/0!	
4-Nitroaniline			mg/l	No GAC	-	#DIV/0!	
Aliphatics >C10-44			mg/l	No GAC	-	#DIV/0!	
Alkalinity (total) (w) Colorimetry			mg/l CaCO3	No GAC	-	294	294
Aluminium (dissolved)	15	EQS*	mg/l	0 of 0	0	#DIV/0!	
Aniline			mg/l	No GAC	-	#DIV/0!	
Azobenzene			mg/l	No GAC	-	#DIV/0!	
Benzyl Alcohol			mg/l	No GAC	-	#DIV/0!	
Bis(2-chloroisopropyl)ether			mg/l	No GAC	-	<0.001	<0.001
Bis(2-ethylhexyl) adipate			mg/l	No GAC	-	#DIV/0!	
Carbalt (dissolved)	3	EQS*	mg/l	0 of 0	0	#DIV/0!	
Cyhalothrin-lambda (w)			mg/l	No GAC	-	#DIV/0!	
Demeton-S (w)			mg/l	No GAC	-	#DIV/0!	
Diflubenzuron (w)	0.001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Diphenylamine			mg/l	No GAC	-	#DIV/0!	
Ecoli (Faecal Coliforms) (w)	0	EUDWS	cfu/100ml	0 of 1	0	<1	<1
Endrin Aldehyde (w)			mg/l	No GAC	-	#DIV/0!	
Endrin Ketone (w)			mg/l	No GAC	-	#DIV/0!	
Fensulphothion (w)			mg/l	No GAC	-	#DIV/0!	
Fluroxypyr (w)			mg/l	No GAC	-	#DIV/0!	
Intestinal Enterococci (Faecal Streptococci/Faecal Enterococci)			cfu/100ml	No GAC	-	5	5
Iron (Soluble)			mg/l	No GAC	-	0.24	0.24
M-Dinitrobenzene			mg/l	No GAC	-	#DIV/0!	
Methabenzthiazuron (w)			mg/l	No GAC	-	#DIV/0!	
Mondisuron (w)			mg/l	No GAC	-	#DIV/0!	
Naphthalene1-methyl-			mg/l	No GAC	-	#DIV/0!	
Naphthols (2-Naphthalenesulfonic acid, 1-hydroxy-)			mg/l	No GAC	-	#DIV/0!	
P-Dinitrobenzene			mg/l	No GAC	-	#DIV/0!	
Perylene			mg/l	No GAC	-	<0.001	<0.001
Resorcinol			mg/l	No GAC	-	#DIV/0!	
Silver (dissolved)	0.05	EQS*	mg/l	0 of 0	0	#DIV/0!	
Telodrin (w)			mg/l	No GAC	-	#DIV/0!	
Terbutryn (w)	0.065	EQS	mg/l	0 of 0	0	#DIV/0!	
Tin (dissolved)	25	EQS*	mg/l	0 of 0	0	#DIV/0!	
Trichloronate (w)			mg/l	No GAC	-	#DIV/0!	
Trimethylphenol			mg/l	No GAC	-	#DIV/0!	
Xylenols & Ethylphenols			mg/l	No GAC	-	#DIV/0!	
Chloroxuron (w)			mg/l	No GAC	-	#DIV/0!	
Demeton-O (w)			mg/l	No GAC	-	#DIV/0!	
Dimefuron (w)			mg/l	No GAC	-	#DIV/0!	
Ethiofencarb (w)			mg/l	No GAC	-	#DIV/0!	
Metoxuron (w)			mg/l	No GAC	-	#DIV/0!	
Pencoxuron (w)			mg/l	No GAC	-	#DIV/0!	
Permethrin I (cis) (w)			mg/l	No GAC	-	#DIV/0!	
Phenmedipham (w)			mg/l	No GAC	-	#DIV/0!	
Prothiotos (Tokuthion) (w)			mg/l	No GAC	-	#DIV/0!	
p,p-DDD (4,4) (w)			mg/l	No GAC	-	#DIV/0!	
p,p-Methoxychlor (w)			mg/l	No GAC	-	#DIV/0!	
cis1,3-Dichloropropene			mg/l	No GAC	-	#DIV/0!	

Concentration exceeds GAC 100.00
Limit of Detection value exceeds GAC <=1

Concentration exceeds GAC Limit of Detection value exceeds GAC										100.00		0.1		Hole Ref		BH310		BH310		GWBH-BH203 12.30		GWBH-BH203 12.30		BH200	
										Sample Ref		384838.09		384845.747		384845.747		389748.863		389748.863					
										Northing		396938.18		396938.18		396938.863		396938.863							
										Hole Elevation (mOD)		32.6		32.6		41.891		41.891							
										Sample Depth (mmb)		4.3		4.3		12.3		12.3							
										Piezometer top (mgb)		8		8		18		18							
										Piezometer base (mgb)		16		16		24		24							
										Sample Date		20/05/22		20/05/22		20/05/22		20/05/22							
										Investigation		326R		326R		NW1604		NW1604							
										Response zone		Collyhurst Sandstone		Collyhurst Sandstone		Collyhurst Sandstone		Collyhurst Sandstone							
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Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<=1

Hole Ref	BH310	BH310	GEO_BH203	GEO_BH203	BH203
Sample Ref	2WBH-BH310 4.3		GWBH-BH203 12.30		100
Easting	384838.00	384838.00	384845.747	384845.747	
Northing	399638.18	399638.18	399748.863	399748.863	
Hole Elevation (mOD)	32.6	32.6	41.891	41.891	
Sample Depth (mngl)	4.3	4.43	12.3	12.4	
Piezometer top (mngl)	8	8	18	18	
Piezometer base (mngl)	16	16	24	24	
Sample Date	20/07/22	05/07/22	20/07/22	05/07/22	26/05/2021
Investigation	326R	326R	NW1604	NW1604	
Response zone	Collyhurst Sandstone	Collyhurst Sandstone	Collyhurst Sandstone	Collyhurst Sandstone	Collyhurst Sandstone St Catherine's Wood

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Average	Max
Bromoxynil (w)	0.1	EQS*	mg/l	0 of 0	0	#DIV/0!	
Clopyralid (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Dicamba (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Diclosa (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Flamprop (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Flamprop-oxypyril (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Ioxynil (w)	0.01	EQS*	mg/l	0 of 0	0	#DIV/0!	
MCPA (w)	0.012	EQS*	mg/l	0 of 0	0	#DIV/0!	
MCPB (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
MCPP (Mecoprop) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Picloram (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Triclopyr (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Bromacil (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Carbetamide (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorbiflum (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorophlam (w)	0.11	EQS*	mg/l	0 of 0	0	#DIV/0!	
Chlorobuturon (w)	0.002	EQS*	mg/l	0 of 0	0	#DIV/0!	
Cyanazine (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Duron (w)	0.0002	EQS	mg/l	0 of 0	0	#DIV/0!	
Isoptoluron (w)	0.0003	EQS	mg/l	0 of 0	0	#DIV/0!	
Linuron (w)	0.0005	EQS	mg/l	0 of 0	0	#DIV/0!	
Monuron (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Primicarb (w)	0.001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Propham (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Cyfluthrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Cypermethrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Delamethrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Fenvalerate (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Permethrin (w)	1E-06	EQS	mg/l	0 of 0	0	#DIV/0!	
Pesticides							
Azin (w)	0.0003	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorothalonil (w)	3.5E-05	EQS	mg/l	0 of 0	0	#DIV/0!	
Dichobenz (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Dieldrin (w)	0.0003	DWS	mg/l	0 of 0	0	#DIV/0!	
Endosulphan I (Alpha) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Endosulphan II (Beta) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Endosulphan Sulphate (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Endrin (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Heptachlor (w)	0	EQS	mg/l	0 of 0	0	#DIV/0!	
Heptachlor epoxide (w)	0.0003	DWS	mg/l	0 of 0	0	#DIV/0!	
Isoodon (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Pendimethalin (w)	1E-06	EQS	mg/l	0 of 0	0	#DIV/0!	
Permethrin II (beta) (w)	1E-06	EQS	mg/l	0 of 0	0	#DIV/0!	
Quintozene (PCNB) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Tecrazene (w)	0.001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Triadimenol (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Triallate (w)	0.00025	EQS*	mg/l	0 of 0	0	#DIV/0!	
Trifluralin (w)	0.0003	EQS	mg/l	0 of 0	0	#DIV/0!	
alpha-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
beta-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
delta-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
gamma-Hexachlorocyclohexane (HCH) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
o,p-DDD (2,4) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
o,p-DDD (2,4) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
o,p-DDT (2,4) (w)	2.5E-05	EQS	mg/l	0 of 0	0	#DIV/0!	
o,p-Methoxychlor (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
p,p-DDD (4,4) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
p,p-DDT (4,4) (w)	0.00001	EQS	mg/l	0 of 0	0	#DIV/0!	
trans-Chlordane (Gamma) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Azinphos-ethyl (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Azinphos-methyl (w)	0.00001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Carbophenothion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Chlorfenvinphos (w)	0.0001	EQS	mg/l	0 of 0	0	#DIV/0!	
Chlorpyrifos (w)	0.0003	EQS	mg/l	0 of 0	0	#DIV/0!	
Chlorpyrifos-methyl (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Gomaphos (w)	0.0003	EQS*	mg/l	0 of 0	0	#DIV/0!	
Diazinon (Dimpylate) (w)	0.00001	EQS	mg/l	0 of 0	0	#DIV/0!	
Dichlorvos (w)	1E-06	EQS	mg/l	0 of 0	0	#DIV/0!	
Dimethoate (w)	0.0048	EQS	mg/l	0 of 0	0	#DIV/0!	
Disulfoton (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Ethion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Fenitrothion (w)	0.00001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Fenitrothion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Malathion (w)	0.00001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Methyl Parathion (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Mevinphos (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Parathion Ethyl Parathion) (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Phorate (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Phosalone (w)	0.0001	DWS	mg/l	0 of 0	0	#DIV/0!	
Prinidaphos-methyl (w)	1.5E-05	EQS*	mg/l	0 of 0	0	#DIV/0!	
Propetamphos (w)	0.00003	EQS*	mg/l	0 of 0	0	#DIV/0!	
Triazaphos (w)	5E-06	EQS*	mg/l	0 of 0	0	#DIV/0!	
Other							
2,3,4,6-Tetrachlorophenol			mg/l	No GAC	-	#DIV/0!	
2,3,5,6-Tetrachlorophenol			mg/l	No GAC	-	#DIV/0!	
2-Nitroaniline			mg/l	No GAC	-	#DIV/0!	
3,4-Methyldiphenyl			mg/l	No GAC	-	#DIV/0!	
3-Nitroaniline			mg/l	No GAC	-	#DIV/0!	
4-Chlorophenyl Phenyl Ether			mg/l	No GAC	-	#DIV/0!	
4-Nitroaniline			mg/l	No GAC	-	#DIV/0!	
Aliphatics >C10-44			mg/l	No GAC	-	#DIV/0!	
Alkalinity (total) (w) Colorimetry	15	EQS*	mg/l	CaCO3	No GAC	#DIV/0!	
Aluminium (dissolved)			mg/l	0 of 0	0	#DIV/0!	
Aniline			mg/l	No GAC	-	#DIV/0!	
Azobenzene			mg/l	No GAC	-	#DIV/0!	
Benzyl Alcohol			mg/l	No GAC	-	#DIV/0!	
Bis(2-chloroisopropyl)ether			mg/l	No GAC	-	#DIV/0!	
Bis(2-ethylhexyl) adipate			mg/l	No GAC	-	#DIV/0!	
Cobalt (dissolved)	3	EQS*	mg/l	2 of 2	0	0.008	
Cyhalothrin-lambda (w)			mg/l	No GAC	-	#DIV/0!	
Demeton-S (w)			mg/l	No GAC	-	#DIV/0!	
Diffenazuron (w)	0.001	EQS*	mg/l	0 of 0	0	#DIV/0!	
Diphenylamine			mg/l	No GAC	-	#DIV/0!	
Ecoti (Faecal Coliforms) (w)	0	EU/DWS	cfu/100ml	0 of 0	0	#DIV/0!	
Endrin Alderhyte (w)			mg/l	No GAC	-	#DIV/0!	
Endrin Ketone (w)			mg/l	No GAC	-	#DIV/0!	
Fenamidiphos (w)			mg/l	No GAC	-	#DIV/0!	
Fluoroxypyr (w)			mg/l	No GAC	-	#DIV/0!	
Intestinal Enterococci (Faecal Streptococci/Faecal Enterococci) (Soluble)			mg/l	No GAC	-	#DIV/0!	
M-Dinitrobenzene			mg/l	No GAC	-	#DIV/0!	
Methabenzthiazuron (w)			mg/l	No GAC	-	#DIV/0!	
Monolinuron (w)			mg/l	No GAC	-	#DIV/0!	
Naphthalene-1-methyl-			mg/l	No GAC	-	#DIV/0!	
Naphthols 2-Naphthalenesulfonic acid, 1-hydroxy-			mg/l	No GAC	-	#DIV/0!	
P-Dinitrobenzene			mg/l	No GAC	-	#DIV/0!	
Perylene			mg/l	No GAC	-	#DIV/0!	
Resorcinol			mg/l	No GAC	-	#DIV/0!	
Silver (dissolved)	0.05	EQS*	mg/l	0 of 0	0	#DIV/0!	
Tetradrin (w)			mg/l	No GAC	-	#DIV/0!	
Terbuthryn (w)	0.065	EQS	mg/l	0 of 0	0	#DIV/0!	
Tin (dissolved)	25	EQS*	mg/l	0 of 0	0	#DIV/0!	
Trichloronate (w)			mg/l	No GAC	-	#DIV/0!	
Trimethylphenyl			mg/l	No GAC	-	#DIV/0!	
Xylenes & Ethylphenols			mg/l	No GAC	-	#DIV/0!	
Chloroxuron (w)			mg/l	No GAC	-	#DIV/0!	
Demeton-Q (w)			mg/l	No GAC	-	#DIV/0!	
Dimelfuron (w)			mg/l	No GAC	-	#DIV/0!	
Ethofencarb (w)			mg/l	No GAC	-	#DIV/0!	
Mesosuron (w)			mg/l	No GAC	-	#DIV/0!	
Pencyuron (w)			mg/l	No GAC	-	#DIV/0!	
Permethrin I (cis) (w)			mg/l	No GAC	-	#DIV/0!	
Phenmedipham (w)			mg/l	No GAC	-	#DIV/0!	
Prothiofos (Tokuthion) (w)			mg/l	No GAC	-	#DIV/0!	
p,p-DDD (4,4) (w)			mg/l	No GAC	-	#DIV/0!	
p,p-Methoxychlor (w)			mg/l	No GAC	-	#DIV/0!	
sas1,3-Dichloropropene			mg/l	No GAC	-	#DIV/0!	

B.1 DQRA Methodology

B.1.1 Overview

This DQRA has been completed using the Environment Agency’s Remedial Targets Methodology (RTM) and supporting worksheet to evaluate the sources identified in **Section 5.1**.

A Level 1 to 3 RTM assessment has been completed to generate soil remedial targets for the known sources of contamination at the site to prevent significant harm to controlled waters.

B.2 Gasworks area

B.2.1 Exposure assumptions

Remediation criteria have been developed for the contaminants identified within the former gasworks area using the Environment Agency’s Remedial Targets Methodology (RTM) workbook¹. Input parameters and outputs from RTM are presented in tables below and later in this Appendix. All contaminants have been modelled to Level 3, including those contaminants identified as being a hazardous substance under the Groundwater Directive² where these are already present in groundwater beneath the site.

Within the site boundary, there is effectively no unsaturated zone that is not made ground and therefore attenuation of contaminants in the unsaturated zone is not relevant. Dilution in groundwater flow within the Collyhurst Sandstone aquifer (the sandstone beneath the former gasworks area) is considered below. Site-specific aquifer parameters were determined from the findings of the ground investigations to support the assessment where possible.

The target concentrations chosen are identified in **Table 15**. The data show that hazardous substances including benzo(a)pyrene are already present in the groundwater beneath the site. In accordance with the Environment Agency’s Remedial Targets Methodology, where contaminants are already present in groundwater, and where the environmental standard is lower than the background concentration, then the BGS baseline concentration should be set as the target concentration. Therefore, for certain contaminants, the concentration in the River Irk upstream of the site or published background concentrations for the region have been used.

B.2.2 Level 1 soil parameters

A summary of the model parameters used in Level 1 is presented in **Table 12** below.

B.2.2.1 Soil porosity

No site-specific data is available for the effective porosity of the soil source. However, this has been estimated based on empirical relationship derived from the soil bulk density and moisture content, using the calculation provided in RTM.

B.2.2.2 Bulk density of soil zone

The gasworks source area sits entirely within the St. Catherine’s Wood area of the site. Laboratory compaction testing on made ground materials taken during the ground investigation within St. Catherine’s Wood confirmed dry bulk densities in the range 1.77 to 2.01 Mg/m³ and an optimum moisture content of 10-14% (see Section 5 of GIR [1]). The median of these ranges has been used in the Level 1 assessment.

B.2.2.3 Fraction of organic carbon

Site-specific data has been used for this parameter, being the average foc content of the made ground.

Table 12 Summary of parameters used in Level 1 RTM

Parameter		Unit	Value used in Level 1 Assessment	Source
Bulk density of soil zone material	p	g/cm ³	1.9	Site measurement
Moisture Content		%	12	Site measurement
Fraction of organic carbon (soil)	foc	-	0.058	Site measurement (made ground)
Water filled soil porosity	□w	fraction	0.228	Calculated based on above parameters
Air filled soil porosity	□a	fraction	0.089	Calculated based on above parameters

B.2.3 Level 2 and 3 aquifer parameters

A summary of the model parameters used in Level 2 and 3 is provided in

¹ Environment Agency (2006) Remedial Targets Methodology

² <http://wfduk.org/resources/groundwater-hazardous-substances-standards>

Table 13 below.

B.2.3.1 Infiltration

The rainfall has been taken from Met Office data³ for the climate station at Woodford for the period 1991 to 2020. The annual average rainfall is 868.40mm/yr (0.0024m/d).

The former gasworks area lies within the St. Catherine’s Wood area that has been used for assessment. The majority of St. Catherine’s Wood is to be used as public open space, however, the gasworks area lies within proposed development plot RB05b, which is currently proposed for a future school use.

The Environment Agency has stated that no infiltration of surface water drainage will be permitted into the ground where adverse levels of contamination are known. Surface water will be collected and stored in permeable paving areas, and an attenuation basin in St. Catherine’s Wood. Surface water will be discharged at a controlled rate into the River Irk via a new outfall.

A value of 10% of the site covered with soft landscaping is considered to be a conservative assessment for Plot RB05b and within this area 100% of rainfall is assumed to infiltrate. The calculated infiltration rate within the gasworks site area is therefore 0.00024m/d.

B.2.3.2 Area of contaminant source

The area of the gasworks has been calculated based on the mapped extent of historical buildings and observations of soil contamination. The approximate area is 953m².

B.2.3.3 Hydraulic conductivity of aquifer in which dilution occurs

No site-specific data is available for hydraulic conductivity within the bedrock aquifers. Published values⁴ for hydraulic conductivity within the Collyhurst Sandstone are >1m/d⁻¹ and the range 3.7 x 10⁻⁵ to 10m/day [7] for the Kinnerton/Collyhurst Sandstone with a geometric mean of 0.4m/d and median of 0.8m/d.

B.2.3.4 Hydraulic gradient of water table

The groundwater hydraulic gradient was calculated from the groundwater elevation measured on site during the spot monitoring rounds undertaken as part of the 2022 GI. A value of 0.032 is used in the assessment, based on two wells which had response zones in the Collyhurst Sandstone (BH309 and BH310).

B.2.3.5 Width of contaminant source perpendicular to groundwater flow

This measurement is taken from the footprint of former gasworks buildings, which has been correlated with observations of contaminated ground during the GI. The width of the source is 22m and the length parallel to groundwater flow is 52m.

B.2.3.6 Mixing zone thickness

The Collyhurst sandstone extends to great depth (over 200m) however the thickness of the mixing zone along the groundwater pathway is substantially less, given that groundwater is believed to discharge into the River Irk. This parameter has been calculated in the model.

B.2.3.7 Bulk density of aquifer materials

The average bulk unit weight value for the Collyhurst Sandstone from ground investigation data is 22kN/m³ or 2.24g/cm³.

B.2.3.8 Aquifer effective porosity

No site-specific data is available for the effective porosity of the aquifer. Literature values quote a porosity at outcrop within the Collyhurst Sandstone of 20 to 24% with an arithmetic mean of 25%.

The estimated porosity using the empirical relationship derived from the soil bulk density (see above), particle density (recommended value provided by the EA in the RTM User Manual) and moisture content (site specific data), together with site-specific moisture content for the Collyhurst Sandstone in the range 8.7 to 17.3% with an average of 12% gives a porosity for the aquifer of 28%.

B.2.3.9 Aquifer fraction of organic carbon

No site-specific data is available for the fraction of organic carbon in the aquifer. Literature values [25] quote a range for Permo-Triassic Sandstones between 0.00028 to 0.0015. A value of 0.0015 has been selected for use in the assessment.

B.2.3.10 Biodegradation

Half-lives for contaminants have been obtained from various literature sources. Dissolved oxygen levels measured in groundwater from the Collyhurst sandstone exceed 0.5mg/l and therefore, based on Environment Agency guidance [27] aerobic conditions are likely to prevail over anaerobic. Therefore, half-lives have been based on aerobic rates of degradation.

The RTM model calculates degradation by using a single decay rate (half-life) to quantify degradation of a contaminant as it migrates towards a selected compliance point. For this assessment, degradation is assumed to be limited to the dissolved phase only. In effect this means that when calculating attenuation caused by degradation the model applies the decay rate to the un-retarded travel time and not the retarded travel time; for slow moving organic contaminants (e.g. PAH and heavier TPH fractions) this substantially reduces the rates of predicted degradation and can under predict levels of degradation.

³ <https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcqrqyr80>

⁴ Baseline Report Series: 8. The Permo-Triassic Sandstones of Manchester and East Cheshire. Groundwater systems and water quality commissioned report CR/03/265N. Technical Report NC/99/74/8. <https://nora.nerc.ac.uk/id/eprint/3573/1/CR03265N.pdf>

Table 13 Summary of parameters used in Level 2 and 3 RTM

Parameter		Unit	Range	Value used in Assessment	Source
Effective Rainfall	E	m/d	0.0024	0.0024	Met Office data
Infiltration Factor		%	10	10	Assumption based on future school site with minimal infiltration
Infiltration rate	Inf	m/d	0.00024	0.00024	Calculated
Length of site parallel to flow	L	m	52	52	Site specific
Hydraulic conductivity of aquifer	K	m/d	3.7x10 ⁻⁵ to 10m/day.	0.4	Literature value, geometric mean
Hydraulic Gradient	I	m/m	0.032	0.032	Site specific
Width of site parallel to flow	W	m	22	22	Site specific
Depth of Mixing	M _z	m	Base of aquifer not penetrated	Calculated	RTM
Bulk density of aquifer materials		g/cm ³	22kN/m ³	2.24	Site specific
Aquifer effective porosity		%	20 to 30%	25	Literature value, arithmetic mean
Distance to compliance point		M	50	50	Estimate
Fraction of organic carbon in sandstone aquifer	Foc	-	0.00028 to 0.0015	0.0015	Literature value

Table 14 Chemical parameters used in RTM

Parameter	Unit	Target concentration	Source	Henry's Law Constant	Source	Kd	Source	Koc (l/kg)	Source	Biodegradation half-life (days)	Source
Benzo(a)pyrene	mg/l	0.00001	Background concentration in Irk upstream of site is <0.00001mg/l (see Table 5), therefore limit of detection applied as target	1.92E-05	A	N/A - non-polar organic	-	1.30E+05	B	294	L
Chromium	mg/l	0.00057	BGS baseline concentration	Not volatile	N/A	4.80E+03	C			N/A	-
TPH - Ali C8-C10	mg/l	0.3	WHO	8.20E+01	TPHCWG	N/A - non-polar organic	-	3.20E+04	B	N/A	-
TPH - Ali C10-C12	mg/l	0.3	WHO	1.30E+02	TPHCWG	N/A - non-polar organic	-	2.50E+05	B	N/A	-
TPH - Ali C12-C16	mg/l	0.3	WHO	5.40E+02	TPHCWG	N/A - non-polar organic	-	5.00E+06	B	N/A	-
TPH - Aro C8-C10	mg/l	0.3	WHO	4.90E-01	TPHCWG	N/A - non-polar organic	-	1.60E+03	B	294	M
TPH - Aro C10-C12	mg/l	0.09	WHO	1.40E-01	TPHCWG	N/A - non-polar organic	-	2.50E+03	B	258	M
TPH - Aro C12-C16	mg/l	0.09	WHO	5.40E-02	TPHCWG	N/A - non-polar organic	-	5.00E+03	B	162	M
TPH - Aro C16-C21	mg/l	0.09	WHO	1.30E-02	TPHCWG	N/A - non-polar organic	-	1.60E+04	B	1310	M
TPH - Aro C21-C35	mg/l	0.09	WHO	6.80E-04	TPHCWG	N/A - non-polar organic	-	1.30E+05	B	1813	M
Anthracene	mg/l	0.0001	EQS	1.81E-04	Arup database	N/A - non-polar organic	-	5.62E+03	I	460	M
Fluoranthene	mg/l	0.000006	EQS	6.29E-05	Environment Agency SR7	N/A - non-polar organic	-	1.82E+04	K	290	L
Lead	mg/l	0.00372	EQS	Not volatile	-	1000	E	-	-	N/A	-
Copper	mg/l	0.00376	BGS baseline concentration	Not volatile	-	501.1872336	F	-	-	N/A	-
Zinc	mg/l	0.1115	BGS baseline concentration, 95%ile	Not volatile	-	501.1872336	G	N/A	-	N/A	-
Nickel	mg/l	0.0153	BGS baseline concentration, 95%ile	Not volatile	-	500		-	-	N/A	-
Ammoniacal Nitrogen	mg/l	0.6	EQS	Not volatile	-	0.4	J	-	-	1095	J
A - Technical report P5-079/TR1, converted for 15C B - CL:AIRE (2017) Petroleum Hydrocarbons in Groundwater C- LQM/CIEH S4UL Report (2015) Publication No. S4UL3213. Assumes pH 6 rather than 7, cautious value D - BP Oil International, 2001 (BP RISC database) E - Thorne et al., 2005 F - Converted from mean log kd from USEPA (2005) http://epa.gov/athens/publications/reports/Ambrose600R05074PartitionCoefficients.pdf TABLE 1 (value 2.7 median) G - Converted from mean log kd from USEPA (2005) http://epa.gov/athens/publications/reports/Ambrose600R05074PartitionCoefficients.pdf TABLE 1 H - Value from Nickel SGV TABLE 4 I - LQM/CIEH 2nd Edition converted from Log koc J - From Buss for clean sand and gravel. Range is 0.2-0.6 for Sherwood Sandstone group, of which Chester Pebble Beds is part. K - Environment Agency SR7 converted from Log Know L – Aerobic biodegradation mid-point, from Howard 1991 M – Aerobic biodegradation maximum, Howard, 1991											

B.2.4 Remediation targets for gasworks

Table 15 below summarises the remediation criteria generated using RTM for the gasworks area, which are designed to be protective of controlled waters.

Table 15 Target concentrations for the protection of controlled waters in former gasworks area

Contaminant	Level 1 target (mg/kg)	Level 1 target (mg/l)	Level 2 target (mg/kg)	Level 2 target (mg/l)	Level 3 target (mg/kg)	Level 3 target (mg/l)
Ammoniacal nitrogen	0.312	0.6	2.38	4.58	4.53	8.72
Benzo(a)Pyrene	0.0754	0.00001	0.576	0.0000764	3.63	0.000481
Fluoranthene	0.00633	0.000006	0.0484	0.0000459	0.311	0.000295
Anthracene	0.0326	0.0001	0.249	0.000764	0.9	0.00274
TPH – Aliphatic C8-C10	558	0.3	4260	2.29	4860	2.61
TPH – Aliphatic C10-C12	4350	0.3	33300	2.29	37900	2.61
TPH – Aliphatic C12-C16	87000	0.3	665000	2.29	758000	2.61
TPH – Aromatic C8-C10	27.9	0.3	213	2.29	1342	14.4
TPH – Aromatic C10-C12	13.1	0.09	99.8	0.688	772	5.3
TPH – Aromatic C12-C16	26.1	0.09	200	0.688	3858	13.3
TPH – Aromatic C16-C21	83.5	0.09	638	0.688	1120	1.2
TPH – Aromatic C21-C35	679	0.09	5190	0.688	8101	1.1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	20-Oct-22	Version:	1
Contaminant	TPH - Aliphatic C8-C10		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C8-C10
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	8.20E+01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	3.20E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.86E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	5.58E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C8-C10		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	2.20E+01	m
Plume thickness in aquifer at source	Sy	6.48E+00	m
Bulk density of aquifer materials	ρ	2.24E+00	g/cm ³
Effective porosity of aquifer	n	2.50E-01	fraction
Hydraulic gradient	i	3.68E-02	fraction
Hydraulic conductivity of saturated aquifer	K	4.00E-01	m/d
Distance to compliance point	x	5.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	4.80E+01	l/kg
Longitudinal dispersivity	ax	5.000	m
Transverse dispersivity	az	0.500	m
Vertical dispersivity	ay	0.050	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	5.89E-02
Retardation factor	R _f	4.31E+02
Decay rate used	λ	1.79E-103
Hydraulic gradient used in aquifer flow down-gradient	i	3.68E-02
Rate of contaminant flow due to retardation	u	1.37E-04
Ratio of Compliance Point to Source Concentration	C _{el} /C _o	8.77E-01
Attenuation factor (C _o /C _{el})	AF	1.14E+00

Remedial Targets

Level 3 Remedial Target	2.61E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _o	8.77E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 3.20E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow} l/kgSorption coefficient for ionised species K_{ow} l/kg

pH value pH

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} 4.80E+01 l/kgSoil water partition coefficient K_d 4.80E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

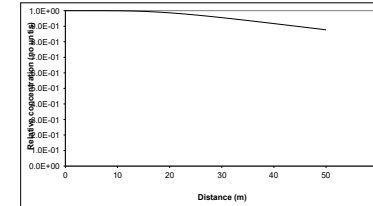
Longitudinal dispersivity	ax	5.00E+00	5.00E+00	2.98E+01	m
Transverse dispersivity	az	5.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	9.99E-01
12.5	9.98E-01
15.0	9.95E-01
17.5	9.91E-01
20.0	9.86E-01
22.5	9.80E-01
25.0	9.72E-01
27.5	9.64E-01
30.0	9.55E-01
32.5	9.46E-01
35.0	9.37E-01
37.5	9.27E-01
40.0	9.17E-01
42.5	9.07E-01
45.0	8.97E-01
47.5	8.87E-01
50.0	8.77E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	1

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	8.20E+01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.86E+03	l/kg
Factor (partitioning between soil and water)		1.86E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

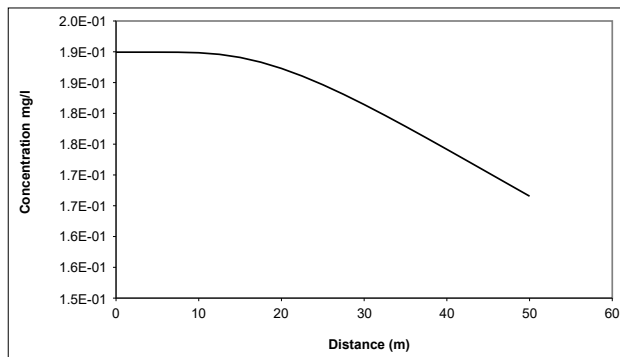
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.45E+00	mg/l	No dilution or attenuation
Level 2	C	1.90E-01	mg/l	Dilution taken into account
Level 3	C	1.67E-01	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.90E-01
2.50	1.90E-01
5.00	1.90E-01
7.50	1.90E-01
10.00	1.90E-01
12.50	1.90E-01
15.00	1.89E-01
17.50	1.88E-01
20.00	1.87E-01
22.50	1.86E-01
25.00	1.85E-01
27.50	1.83E-01
30.00	1.81E-01
32.50	1.80E-01
35.00	1.78E-01
37.50	1.76E-01
40.00	1.74E-01
42.50	1.72E-01
45.00	1.70E-01
47.50	1.68E-01
50.00	1.67E-01



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	20-Oct-22	Version:	1
Contaminant	TPH - Aliphatic C10-C12		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C10-C12
Target concentration	0.3 mg/l

Input Parameters
Standard entry

Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.30E+02	dimensionless	Literature value	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg	Literature value
----------------------------------	----	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground
Organic carbon partition coefficient	Koc	2.50E+05	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 1.45E+04 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	4.35E+03	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aliphatic C10-C12** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation
				Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00		
Level 2 Remedial Target		2.29E+00 or 3.33E+04	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.
				For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C10-C12		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	2.20E+01	m
Plume thickness in aquifer at source	Sy	6.48E+00	m
Bulk density of aquifer materials	ρ	2.24E+00	g/cm ³
Effective porosity of aquifer	n	2.50E-01	fraction
Hydraulic gradient	i	3.68E-02	fraction
Hydraulic conductivity of saturated aquifer	K	4.00E-01	m/d
Distance to compliance point	x	5.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	3.75E+02	l/kg
Longitudinal dispersivity	ax	5.000	m
Transverse dispersivity	az	0.500	m
Vertical dispersivity	ay	0.050	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	5.89E-02
Retardation factor	R _f	3.36E+03
Decay rate used	λ	2.29E-104
Hydraulic gradient used in aquifer flow down-gradient	i	3.68E-02
Rate of contaminant flow due to retardation	u	1.75E-05
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	8.77E-01
Attenuation factor (C ₀ /C _{el})	AF	1.14E+00

Remedial Targets

Level 3 Remedial Target	2.61E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	8.77E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 2.50E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow} l/kgSorption coefficient for ionised species K_{ow} l/kg

pH value pH

Acid dissociation constant pK_a l/kgFraction of organic carbon in aquifer f_{oc} fractionSoil water partition coefficient K_d 3.75E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

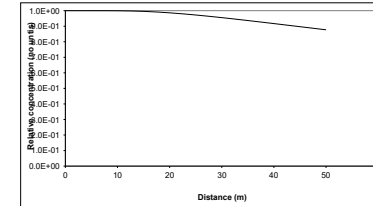
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	5.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	(No units)
2.5	1.0E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	9.99E-01
12.5	9.98E-01
15.0	9.95E-01
17.5	9.91E-01
20.0	9.86E-01
22.5	9.80E-01
25.0	9.72E-01
27.5	9.64E-01
30.0	9.55E-01
32.5	9.46E-01
35.0	9.37E-01
37.5	9.27E-01
40.0	9.17E-01
42.5	9.07E-01
45.0	8.97E-01
47.5	8.87E-01
50.0	8.77E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	1

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	1.30E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.45E+04	l/kg
Factor (partitioning between soil and water)		1.45E+04	dimensionless

Level 2 Parameters

Dilution Factor DF

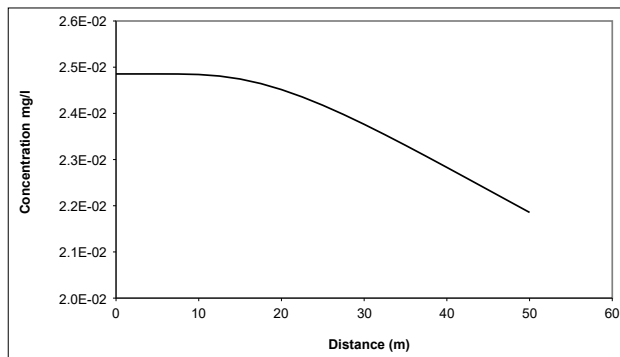
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.86E-01	mg/l	No dilution or attenuation
Level 2	C	2.44E-02	mg/l	Dilution taken into account
Level 3	C	2.14E-02	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.44E-02
2.50	2.44E-02
5.00	2.44E-02
7.50	2.44E-02
10.00	2.43E-02
12.50	2.43E-02
15.00	2.42E-02
17.50	2.41E-02
20.00	2.40E-02
22.50	2.39E-02
25.00	2.37E-02
27.50	2.35E-02
30.00	2.33E-02
32.50	2.30E-02
35.00	2.28E-02
37.50	2.26E-02
40.00	2.23E-02
42.50	2.21E-02
45.00	2.18E-02
47.50	2.16E-02
50.00	2.14E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	TPH - Aliphatic C12-C16		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C12-C16
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	5.40E+02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	5.00E+06	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	2.90E+05	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	8.70E+04	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **TPH - Aliphatic C12-C16** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00		
Level 2 Remedial Target		2.29E+00 or 6.65E+05	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C12-C16		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days	No degradation assumed
Calculated decay rate	λ	7.70E-101	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	6.48E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	n	2.50E-01	fraction	Literature value
Hydraulic gradient	i	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	4.00E-01	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+99	days	time variant options only
Parameters values determined from options				
Partition coefficient	Kd	7.50E+03	l/kg	see options
Longitudinal dispersivity	ax	5.000	m	see options
Transverse dispersivity	az	0.500	m	see options
Vertical dispersivity	ay	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	5.89E-02 m/d
Retardation factor	R _f	6.72E+04
Decay rate used	λ	1.15E-105 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	3.68E-02
Rate of contaminant flow due to retardation	u	8.77E-07 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	8.77E-01
Attenuation factor (C ₀ /C _{el})	AF	1.14E+00

Remedial Targets

Level 3 Remedial Target	2.61E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	7.58E+05	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	8.77E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 5.00E+06 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc} fractionSoil water partition coefficient K_d 7.50E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

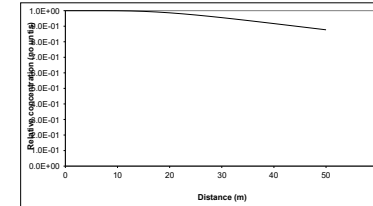
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	5.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	9.99E-01
12.5	9.98E-01
15.0	9.95E-01
17.5	9.91E-01
20.0	9.86E-01
22.5	9.80E-01
25.0	9.72E-01
27.5	9.64E-01
30.0	9.55E-01
32.5	9.46E-01
35.0	9.37E-01
37.5	9.27E-01
40.0	9.17E-01
42.5	9.07E-01
45.0	8.97E-01
47.5	8.87E-01
50.0	8.77E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	5.40E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	2.90E+05	l/kg
Factor (partitioning between soil and water)		2.90E+05	dimensionless

Level 2 Parameters

Dilution Factor DF

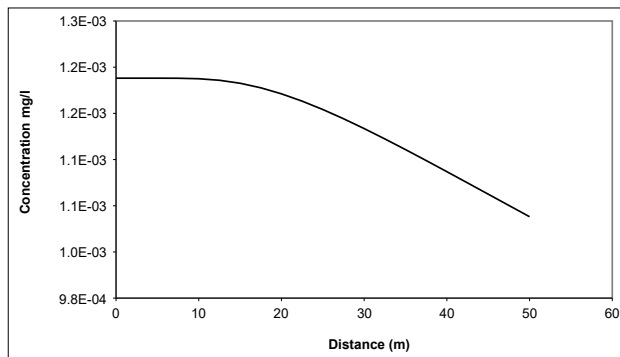
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	9.31E-03	mg/l	No dilution or attenuation
Level 2	C	1.22E-03	mg/l	Dilution taken into account
Level 3	C	1.07E-03	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.22E-03
2.50	1.22E-03
5.00	1.22E-03
7.50	1.22E-03
10.00	1.22E-03
12.50	1.22E-03
15.00	1.21E-03
17.50	1.21E-03
20.00	1.20E-03
22.50	1.19E-03
25.00	1.18E-03
27.50	1.17E-03
30.00	1.16E-03
32.50	1.15E-03
35.00	1.14E-03
37.50	1.13E-03
40.00	1.12E-03
42.50	1.10E-03
45.00	1.09E-03
47.50	1.08E-03
50.00	1.07E-03



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	01-Nov-22	Version:	2
Contaminant	Ammoniacal nitrogen (ammonium)		
Target Concentration (C _T)	0.6	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Ammoniacal nitrogen (ammoni
Target concentration	C _T 0.6 mg/l

Input Parameters

Standard entry

Water filled soil porosity	θ _w	2.28E-01	fraction
Air filled soil porosity	θ _a	8.90E-02	fraction
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless

Calculated
Calculated
Site measurement for made ground
N/A

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	K _d	4.00E-01	l/kg
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Literature value from Buss (EA)

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	f _{oc}		fraction
Organic carbon partition coefficient	K _{oc}		l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg
Sorption coefficient for ionised species	K _{oc,i}		l/kg
pH value	pH		pH units
Acid dissociation constant	pK _a		
Fraction of organic carbon (in soil)	f _{oc}		fraction

Soil water partition coefficient used in Level Assessment K_d 4.00E-01 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	3.12E-01	mg/kg	(for comparison with soil analyses)
	or		
	0.6	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **Ammoniacal nitrogen (ammo)** from Level 1
0.6 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00	
Level 2 Remedial Target		4.58E+00 or 2.38E+00	mg/l or mg/kg
For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.			
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water			

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Ammoniacal nitrogen (amm)		from Level 1
Target Concentration	Cr	0.6	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.10E+03	days	Buss et al 2004
Calculated decay rate	6.33E-04	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks area
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	4.00E-01	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	4.58E+00	fraction
Decay rate used	1.38E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	1.29E-02	m/d
Ratio of Compliance Point to Source Concentration	5.26E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.90E+00	fraction

Remedial Targets

Level 3 Remedial Target	8.72E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	5.26E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 4.00E-01 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc fraction

Organic carbon partition coefficient Koc l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa fraction

Fraction of organic carbon in aquifer foc fraction

Soil water partition coefficient Kd 4.00E-01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

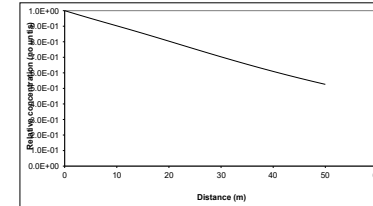
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	9.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	9.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
2.5	9.75E-01
5.0	9.50E-01
7.5	9.25E-01
10.0	9.02E-01
12.5	8.78E-01
15.0	8.54E-01
17.5	8.29E-01
20.0	8.04E-01
22.5	7.78E-01
25.0	7.53E-01
27.5	7.28E-01
30.0	7.03E-01
32.5	6.79E-01
35.0	6.55E-01
37.5	6.32E-01
40.0	6.09E-01
42.5	5.87E-01
45.0	5.66E-01
47.5	5.46E-01
50.0	5.26E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	4.00E-01	l/kg
Factor (partitioning between soil and water)		5.20E-01	dimensionless

Level 2 Parameters

Dilution Factor DF

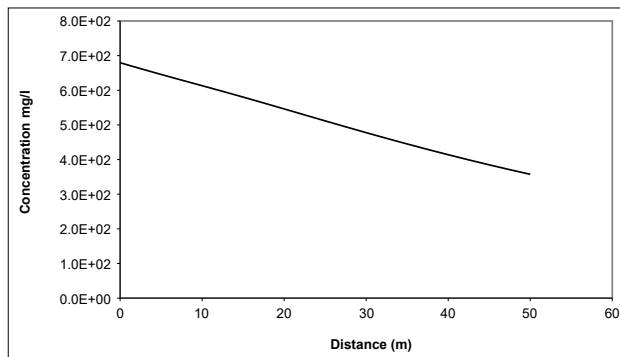
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.19E+03 mg/l	No dilution or attenuation
Level 2	C	6.80E+02 mg/l	Dilution taken into account
Level 3	C	3.57E+02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	6.80E+02
2.50	6.62E+02
5.00	6.46E+02
7.50	6.29E+02
10.00	6.13E+02
12.50	5.97E+02
15.00	5.80E+02
17.50	5.63E+02
20.00	5.46E+02
22.50	5.29E+02
25.00	5.12E+02
27.50	4.95E+02
30.00	4.78E+02
32.50	4.61E+02
35.00	4.45E+02
37.50	4.29E+02
40.00	4.14E+02
42.50	3.99E+02
45.00	3.85E+02
47.50	3.71E+02
50.00	3.57E+02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	Anthracene		
Target Concentration (C _T)	1.00E-04	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Anthracene
Target concentration	0.0001 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value
Water filled soil porosity θ_w	2.28E-01	fraction	Calculated
Air filled soil porosity θ_a	8.90E-02	fraction	Calculated
Bulk density of soil zone material ρ	1.90E+00	g/cm ³	Site measurement for made ground
Henry's Law constant H	1.84E-04	dimensionless	Literature value

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg	Literature value
----------------------------------	----	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground
Organic carbon partition coefficient	Koc	5.62E+03	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 3.26E+02 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	3.26E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.0001	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Anthraxene		from Level 1
Target Concentration	Cr	0.0001	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	4.60E+02	days	Howard, 1991
Calculated decay rate	1.51E-03	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	8.43E+00	l/kg see options
Longitudinal dispersivity	ax	5.000	m see options
Transverse dispersivity	az	0.500	m see options
Vertical dispersivity	ay	0.050	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	5.89E-02 m/d
Retardation factor	Rf	7.65E+01 fraction
Decay rate used	λ	1.97E-05 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	3.68E-02 fraction
Rate of contaminant flow due to retardation	u	7.70E-04 m/d
Ratio of Compliance Point to Source Concentration	C _{ED} /C ₀	2.78E-01 fraction
Attenuation factor (C ₀ /C _{ED})	AF	3.59E+00 fraction

Remedial Targets

Level 3 Remedial Target	2.75E-03	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	8.95E-01	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{ED} /C ₀	2.78E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 5.62E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 8.43E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

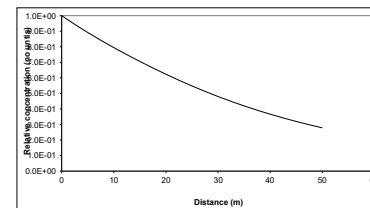
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	5.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
2.5	9.44E-01
5.0	8.92E-01
7.5	8.42E-01
10.0	7.95E-01
12.5	7.49E-01
15.0	7.06E-01
17.5	6.64E-01
20.0	6.23E-01
22.5	5.85E-01
25.0	5.48E-01
27.5	5.13E-01
30.0	4.80E-01
32.5	4.49E-01
35.0	4.19E-01
37.5	3.92E-01
40.0	3.66E-01
42.5	3.42E-01
45.0	3.19E-01
47.5	2.98E-01
50.0	2.78E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source. Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	1.84E-04	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.26E+02	l/kg
Factor (partitioning between soil and water)		3.26E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

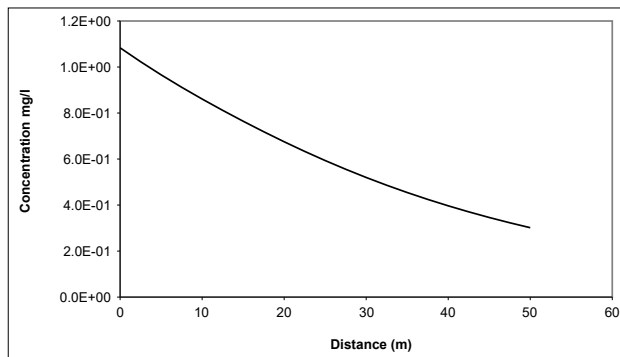
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	8.28E+00 mg/l	No dilution or attenuation
Level 2	C	1.08E+00 mg/l	Dilution taken into account
Level 3	C	3.02E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.08E+00
2.50	1.02E+00
5.00	9.66E-01
7.50	9.12E-01
10.00	8.61E-01
12.50	8.12E-01
15.00	7.64E-01
17.50	7.19E-01
20.00	6.75E-01
22.50	6.33E-01
25.00	5.93E-01
27.50	5.56E-01
30.00	5.20E-01
32.50	4.86E-01
35.00	4.54E-01
37.50	4.25E-01
40.00	3.97E-01
42.50	3.71E-01
45.00	3.46E-01
47.50	3.23E-01
50.00	3.02E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	01-Nov-22	Version:	2
Contaminant	TPH - Aromatic C8-C10		
Target Concentration (C_T)	3.00E-01	mg/l	Origin of C_T: WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C8-C10
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	4.90E-01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.60E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	9.28E+01	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	2.79E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C8-C10		from Level 1
Target Concentration	0.3	mg/l	from Level 1
Dilution Factor	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.94E+02	days	Howard, 1991
Calculated decay rate	2.36E-03	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.40E+00	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	2.25E+01	fraction
Decay rate used	1.05E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	2.62E-03	m/d
Ratio of Compliance Point to Source Concentration	1.59E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	6.30E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.44E+01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₀	1.59E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.60E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.40E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

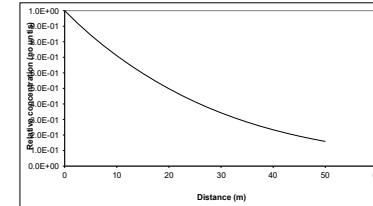
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	5.00E+00	2.98E+00	m
Transverse dispersivity	az	5.00E+00	2.98E+01	m
Vertical dispersivity	ay	5.00E+00	2.98E+02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
2.5	9.19E-01
5.0	8.43E-01
7.5	7.74E-01
10.0	7.10E-01
12.5	6.51E-01
15.0	5.96E-01
17.5	5.45E-01
20.0	4.98E-01
22.5	4.54E-01
25.0	4.14E-01
27.5	3.77E-01
30.0	3.43E-01
32.5	3.11E-01
35.0	2.83E-01
37.5	2.57E-01
40.0	2.34E-01
42.5	2.12E-01
45.0	1.93E-01
47.5	1.75E-01
50.0	1.59E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source. Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	4.90E-01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.28E+01	l/kg
Factor (partitioning between soil and water)		9.29E+01	dimensionless

Level 2 Parameters

Dilution Factor DF

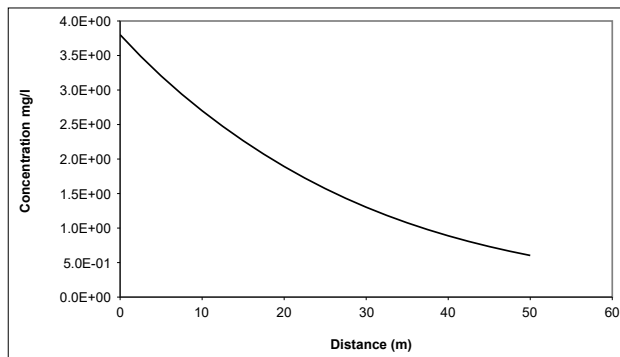
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.91E+01 mg/l	No dilution or attenuation
Level 2	C	3.80E+00 mg/l	Dilution taken into account
Level 3	C	6.03E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.80E+00
2.50	3.49E+00
5.00	3.20E+00
7.50	2.94E+00
10.00	2.70E+00
12.50	2.47E+00
15.00	2.27E+00
17.50	2.07E+00
20.00	1.89E+00
22.50	1.73E+00
25.00	1.57E+00
27.50	1.43E+00
30.00	1.30E+00
32.50	1.18E+00
35.00	1.08E+00
37.50	9.78E-01
40.00	8.88E-01
42.50	8.06E-01
45.00	7.32E-01
47.50	6.65E-01
50.00	6.03E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH	Version:	2
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C10-C12		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C10-C12
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.40E-01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	2.50E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.45E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	1.31E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C10-C12** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Not used in calculation

Not used in calculation

Calculated Parameters

Dilution Factor	DF	7.64E+00
Level 2 Remedial Target		6.88E-01 mg/l or 9.98E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C10-C12		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.58E+02	days	Howard, 1991
Calculated decay rate	2.69E-03	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	3.75E+00	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	3.46E+01	fraction
Decay rate used	7.76E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	1.70E-03	m/d
Ratio of Compliance Point to Source Concentration	1.29E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	7.73E+00	fraction

Remedial Targets

Level 3 Remedial Target	5.32E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	7.72E+02	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	50	m	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 2.50E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} 3.75E+00 l/kg

Soil water partition coefficient Kd l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

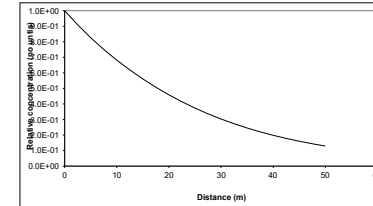
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	5.00E+00	2.98E+00	m
Transverse dispersivity	az	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
2.5	9.09E-01
5.0	8.26E-01
7.5	7.50E-01
10.0	6.82E-01
12.5	6.19E-01
15.0	5.61E-01
17.5	5.07E-01
20.0	4.59E-01
22.5	4.14E-01
25.0	3.73E-01
27.5	3.36E-01
30.0	3.03E-01
32.5	2.73E-01
35.0	2.45E-01
37.5	2.21E-01
40.0	1.98E-01
42.5	1.78E-01
45.0	1.60E-01
47.5	1.44E-01
50.0	1.29E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source. Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	1.40E-01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.45E+02	l/kg
Factor (partitioning between soil and water)		1.45E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

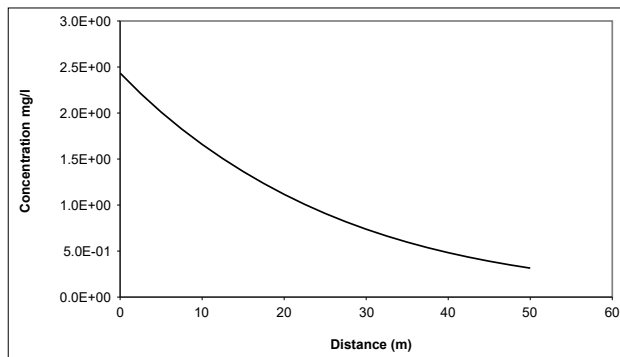
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.86E+01 mg/l	No dilution or attenuation
Level 2	C	2.43E+00 mg/l	Dilution taken into account
Level 3	C	3.15E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.43E+00
2.50	2.21E+00
5.00	2.01E+00
7.50	1.83E+00
10.00	1.66E+00
12.50	1.51E+00
15.00	1.36E+00
17.50	1.24E+00
20.00	1.12E+00
22.50	1.01E+00
25.00	9.09E-01
27.50	8.19E-01
30.00	7.37E-01
32.50	6.64E-01
35.00	5.97E-01
37.50	5.37E-01
40.00	4.83E-01
42.50	4.34E-01
45.00	3.90E-01
47.50	3.50E-01
50.00	3.15E-01



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First released: 2006. Version 3.2: January 2013

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Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH	Version:	2
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C12-C16		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

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The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C12-C16
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	5.40E-02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	5.00E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	2.90E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	2.61E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C12-C16** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Not used in calculation

Not used in calculation

Calculated Parameters

Dilution Factor	DF	7.64E+00
Level 2 Remedial Target		6.88E-01 mg/l or 2.00E+02 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C12-C16		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.62E+02	days	Howard, 1991
Calculated decay rate	4.28E-03	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of site
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	7.50E+00	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	6.82E+01	fraction
Decay rate used	6.27E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	8.64E-04	m/d
Ratio of Compliance Point to Source Concentration	5.17E-02	fraction
Attenuation factor (C ₀ /C ₁₀)	1.93E+01	fraction

Remedial Targets

Level 3 Remedial Target	1.33E+01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	5.17E-02	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 5.00E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 7.50E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

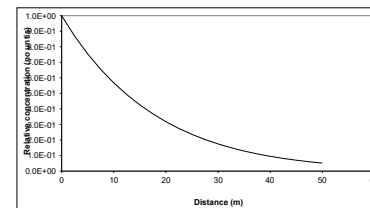
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	5.00E+00	2.98E-01	m
Transverse dispersivity	az	5.00E+00	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
2.5	8.68E-01
5.0	7.53E-01
7.5	6.54E-01
10.0	5.67E-01
12.5	4.92E-01
15.0	4.26E-01
17.5	3.68E-01
20.0	3.18E-01
22.5	2.74E-01
25.0	2.36E-01
27.5	2.03E-01
30.0	1.75E-01
32.5	1.50E-01
35.0	1.29E-01
37.5	1.11E-01
40.0	9.53E-02
42.5	8.18E-02
45.0	7.02E-02
47.5	6.03E-02
50.0	5.17E-02

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	5.40E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	2.90E+02	l/kg
Factor (partitioning between soil and water)		2.90E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

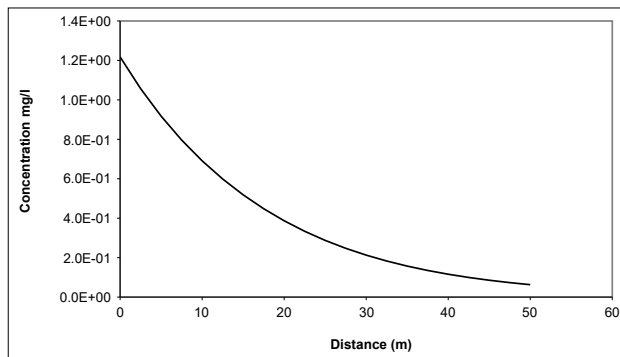
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	9.31E+00 mg/l	No dilution or attenuation
Level 2	C	1.22E+00 mg/l	Dilution taken into account
Level 3	C	6.30E-02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.22E+00
2.50	1.06E+00
5.00	9.18E-01
7.50	7.96E-01
10.00	6.91E-01
12.50	5.99E-01
15.00	5.19E-01
17.50	4.48E-01
20.00	3.87E-01
22.50	3.34E-01
25.00	2.87E-01
27.50	2.47E-01
30.00	2.13E-01
32.50	1.83E-01
35.00	1.57E-01
37.50	1.35E-01
40.00	1.16E-01
42.50	9.96E-02
45.00	8.55E-02
47.50	7.34E-02
50.00	6.30E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	01-Nov-22	Version:	2
Contaminant	TPH - Aromatic C16-C21		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C16-C21
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.30E-02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.60E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	9.28E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	8.35E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C16-C21** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Not used in calculation

Not used in calculation

Calculated Parameters

Dilution Factor	DF	7.64E+00
Level 2 Remedial Target		6.88E-01 mg/l or 6.38E+02 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C16-C21		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.31E+03	days	Howard, 1991
Calculated decay rate	5.29E-04	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.40E+01	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	2.16E+02	fraction
Decay rate used	2.45E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	2.73E-04	m/d
Ratio of Compliance Point to Source Concentration	5.70E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.75E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.21E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	5.70E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 1.60E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} 2.40E+01 l/kgSoil water partition coefficient K_d 2.40E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

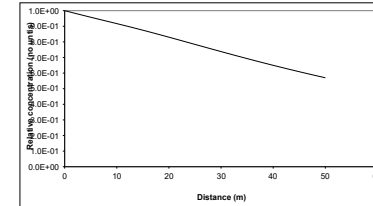
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	5.00E+00	2.98E+01	m
Transverse dispersivity	az	5.00E+00	2.98E+01	m
Vertical dispersivity	ay	5.00E+00	2.98E+02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
2.5	9.79E-01
5.0	9.58E-01
7.5	9.37E-01
10.0	9.17E-01
12.5	8.96E-01
15.0	8.75E-01
17.5	8.53E-01
20.0	8.30E-01
22.5	8.07E-01
25.0	7.84E-01
27.5	7.61E-01
30.0	7.38E-01
32.5	7.15E-01
35.0	6.93E-01
37.5	6.71E-01
40.0	6.50E-01
42.5	6.29E-01
45.0	6.09E-01
47.5	5.89E-01
50.0	5.70E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.28E+02	l/kg
Factor (partitioning between soil and water)		9.28E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

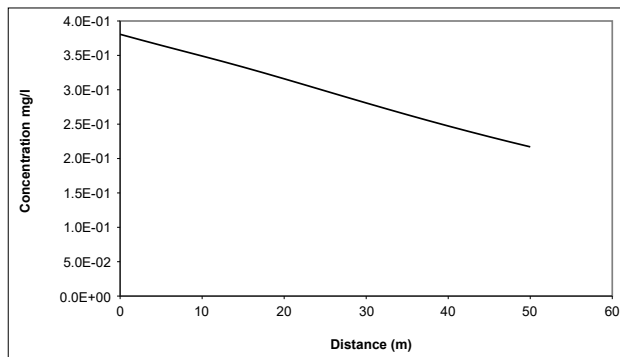
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.91E+00 mg/l	No dilution or attenuation
Level 2	C	3.81E-01 mg/l	Dilution taken into account
Level 3	C	2.17E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.81E-01
2.50	3.73E-01
5.00	3.65E-01
7.50	3.57E-01
10.00	3.49E-01
12.50	3.41E-01
15.00	3.33E-01
17.50	3.25E-01
20.00	3.16E-01
22.50	3.07E-01
25.00	2.98E-01
27.50	2.90E-01
30.00	2.81E-01
32.50	2.72E-01
35.00	2.64E-01
37.50	2.55E-01
40.00	2.47E-01
42.50	2.39E-01
45.00	2.32E-01
47.50	2.24E-01
50.00	2.17E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	TPH - Aromatic C21-C35		
Target Concentration (C_T)	9.00E-02	mg/l	Origin of C_T: WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C21-C35
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.80E-04	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.79E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C21-C35		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks

Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.81E+03	days	Howard, 1991
Calculated decay rate	3.82E-04	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of site
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	1.75E+03	fraction
Decay rate used	2.19E-07	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	3.37E-05	m/d
Ratio of Compliance Point to Source Concentration	6.40E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.56E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.07E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	6.40E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

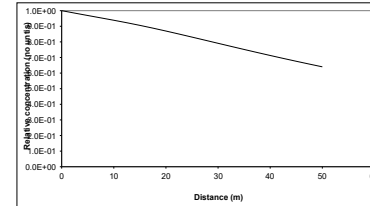
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	5.00E+00	2.98E-01	m
Transverse dispersivity	az	5.00E+00	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
2.5	9.84E-01
5.0	9.69E-01
7.5	9.54E-01
10.0	9.39E-01
12.5	9.23E-01
15.0	9.06E-01
17.5	8.88E-01
20.0	8.69E-01
22.5	8.50E-01
25.0	8.31E-01
27.5	8.11E-01
30.0	7.91E-01
32.5	7.71E-01
35.0	7.51E-01
37.5	7.32E-01
40.0	7.13E-01
42.5	6.94E-01
45.0	6.76E-01
47.5	6.58E-01
50.0	6.40E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	6.80E-04	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

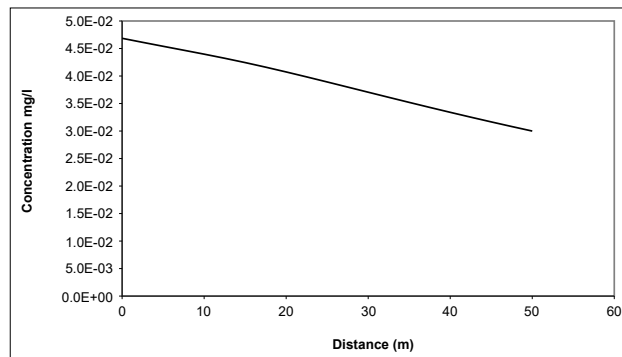
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	3.58E-01 mg/l	No dilution or attenuation
Level 2	C	4.69E-02 mg/l	Dilution taken into account
Level 3	C	3.00E-02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	4.69E-02
2.50	4.61E-02
5.00	4.54E-02
7.50	4.47E-02
10.00	4.40E-02
12.50	4.32E-02
15.00	4.24E-02
17.50	4.16E-02
20.00	4.07E-02
22.50	3.98E-02
25.00	3.89E-02
27.50	3.80E-02
30.00	3.71E-02
32.50	3.61E-02
35.00	3.52E-02
37.50	3.43E-02
40.00	3.34E-02
42.50	3.25E-02
45.00	3.17E-02
47.50	3.08E-02
50.00	3.00E-02



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	Benzo(a)Pyrene		
Target Concentration (C _T)	1.00E-05	mg/l	Origin of C _T : Background concentration in Irk

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Benzo(a)Pyrene
Target concentration	0.00001 mg/l

Input Parameters
Standard entry

Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.92E-05	dimensionless	Literature value	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg	Literature value
----------------------------------	----	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 7.54E+03 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	7.54E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.00001	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Benzo(a)Pyrene** from Level 1
0.00001 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00		
Level 2 Remedial Target		7.64E-05 or 5.76E-01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzo(a)Pyrene		from Level 1
Target Concentration	Cr	0.00001	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.94E+02	days	Howard, 1991
Calculated decay rate	2.36E-03	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	1.75E+03	fraction
Decay rate used	1.35E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	3.37E-05	m/d
Ratio of Compliance Point to Source Concentration	1.59E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	6.30E+00	fraction

Remedial Targets

Level 3 Remedial Target	4.81E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	3.63E+00	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	50	m	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

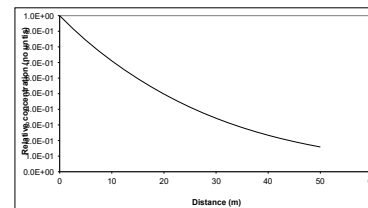
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	9.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	9.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance Relative concentration

(No units)

0 1.0E+00

2.5 9.19E-01

5.0 8.43E-01

7.5 7.74E-01

10.0 7.10E-01

12.5 6.51E-01

15.0 5.96E-01

17.5 5.45E-01

20.0 4.98E-01

22.5 4.54E-01

25.0 4.14E-01

27.5 3.77E-01

30.0 3.43E-01

32.5 3.11E-01

35.0 2.83E-01

37.5 2.57E-01

40.0 2.34E-01

42.5 2.12E-01

45.0 1.93E-01

47.5 1.75E-01

50.0 1.59E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	1.92E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

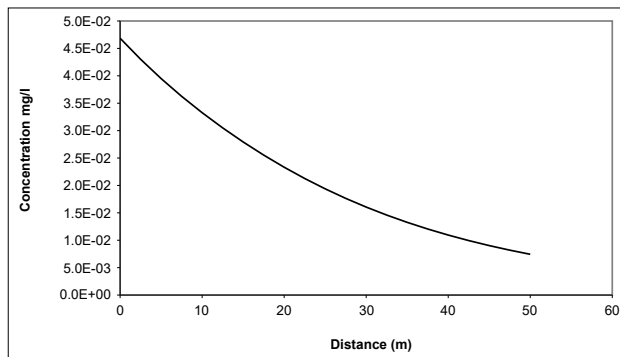
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	3.58E-01 mg/l	No dilution or attenuation
Level 2	C	4.69E-02 mg/l	Dilution taken into account
Level 3	C	7.44E-03 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	4.69E-02
2.50	4.30E-02
5.00	3.95E-02
7.50	3.63E-02
10.00	3.33E-02
12.50	3.05E-02
15.00	2.79E-02
17.50	2.55E-02
20.00	2.33E-02
22.50	2.13E-02
25.00	1.94E-02
27.50	1.76E-02
30.00	1.61E-02
32.50	1.46E-02
35.00	1.33E-02
37.50	1.21E-02
40.00	1.09E-02
42.50	9.94E-03
45.00	9.03E-03
47.50	8.19E-03
50.00	7.44E-03



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	Benzo(a)Pyrene		
Target Concentration (C _T)	1.00E-05	mg/l	Origin of C _T : Background concentration in Irk

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Benzo(a)Pyrene
Target concentration	0.00001 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.92E-05	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	7.54E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.00001	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Benzo(a)Pyrene** from Level 1
0.00001 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00		
Level 2 Remedial Target		7.64E-05 or 5.76E-01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	Benzo(a)Pyrene		from Level 1
Target Concentration	0.00001	mg/l	from Level 1
Dilution Factor	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.06E+03	days	Howard, 1991
Calculated decay rate	6.54E-04	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	1.75E+03	fraction
Decay rate used	3.74E-07	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	3.37E-05	m/d
Ratio of Compliance Point to Source Concentration	5.18E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.93E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.48E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	50	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	5.18E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

Transverse dispersivity

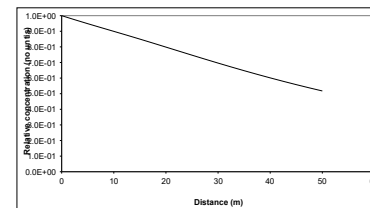
Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
2.5	9.74E-01
5.0	9.49E-01
7.5	9.24E-01
10.0	8.99E-01
12.5	8.75E-01
15.0	8.50E-01
17.5	8.24E-01
20.0	7.99E-01
22.5	7.73E-01
25.0	7.47E-01
27.5	7.21E-01
30.0	6.96E-01
32.5	6.72E-01
35.0	6.47E-01
37.5	6.24E-01
40.0	6.01E-01
42.5	5.79E-01
45.0	5.58E-01
47.5	5.37E-01
50.0	5.18E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: #####
Version: 3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	1.92E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

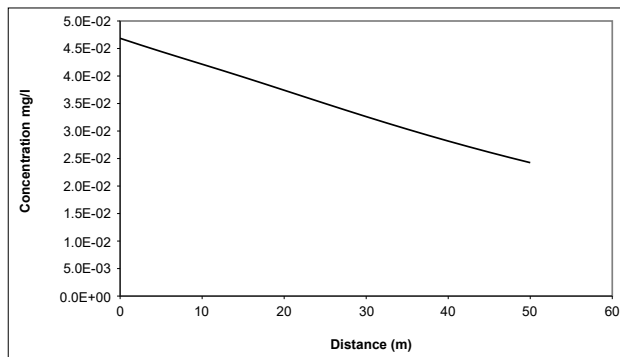
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	3.58E-01 mg/l	No dilution or attenuation
Level 2	C	4.69E-02 mg/l	Dilution taken into account
Level 3	C	2.42E-02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	4.69E-02
2.50	4.56E-02
5.00	4.44E-02
7.50	4.33E-02
10.00	4.21E-02
12.50	4.10E-02
15.00	3.98E-02
17.50	3.86E-02
20.00	3.74E-02
22.50	3.62E-02
25.00	3.50E-02
27.50	3.38E-02
30.00	3.26E-02
32.50	3.15E-02
35.00	3.03E-02
37.50	2.92E-02
40.00	2.82E-02
42.50	2.71E-02
45.00	2.61E-02
47.50	2.52E-02
50.00	2.42E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH	Version:	2
Date:	01-Nov-22		
Contaminant	Fluoranthene		
Target Concentration (C _T)	6.00E-06	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Fluoranthene
Target concentration	0.000006 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	2.28E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	θ_a	8.90E-02	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.29E-05	dimensionless	Literature value	
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.82E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.33E-03	mg/kg	(for comparison with soil analyses)
	or		
	0.000006	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Fluoranthene**
0.000006 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation
Not used in calculation				
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	Not used in calculation
Calculate				
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00	
Level 2 Remedial Target		4.59E-05	mg/l
		or	
		4.84E-02	mg/kg
For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.			
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water			

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Fluoranthene		from Level 1
Target Concentration	Cr	0.000006	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.99E+03	days	Pubchem
Calculated decay rate	3.48E-04	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.73E+01	l/kg see options
Longitudinal dispersivity	ax	5.000	m see options
Transverse dispersivity	az	0.500	m see options
Vertical dispersivity	ay	0.050	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	2.46E+02	fraction
Decay rate used	1.42E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	2.40E-04	m/d
Ratio of Compliance Point to Source Concentration	C _{ED} /C ₀	fraction
Attenuation factor (C ₀ /C _{ED})	AF	1.52E+00

Remedial Targets

Level 3 Remedial Target	6.97E-05	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	7.36E-02	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{ED} /C ₀	6.58E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

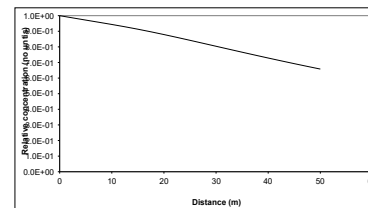
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	5.00E+00	2.98E-01	m
Transverse dispersivity	az	5.00E+00	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration
From calculation sheet	(No units)
Distance	Relative concentration
0	1.0E+00
2.5	9.86E-01
5.0	9.72E-01
7.5	9.58E-01
10.0	9.44E-01
12.5	9.29E-01
15.0	9.13E-01
17.5	8.97E-01
20.0	8.79E-01
22.5	8.61E-01
25.0	8.42E-01
27.5	8.23E-01
30.0	8.04E-01
32.5	7.85E-01
35.0	7.66E-01
37.5	7.47E-01
40.0	7.29E-01
42.5	7.10E-01
45.0	6.93E-01
47.5	6.75E-01
50.0	6.58E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	6.29E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg
Factor (partitioning between soil and water)		1.06E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

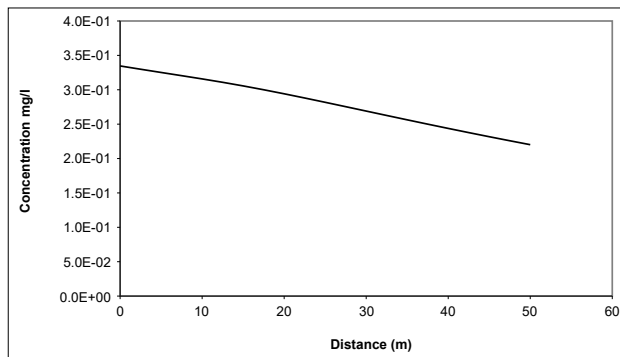
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.56E+00 mg/l	No dilution or attenuation
Level 2	C	3.35E-01 mg/l	Dilution taken into account
Level 3	C	2.20E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.35E-01
2.50	3.30E-01
5.00	3.25E-01
7.50	3.20E-01
10.00	3.16E-01
12.50	3.11E-01
15.00	3.06E-01
17.50	3.00E-01
20.00	2.94E-01
22.50	2.88E-01
25.00	2.82E-01
27.50	2.75E-01
30.00	2.69E-01
32.50	2.63E-01
35.00	2.56E-01
37.50	2.50E-01
40.00	2.44E-01
42.50	2.38E-01
45.00	2.32E-01
47.50	2.26E-01
50.00	2.20E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Gasworks area		
Completed by:	DH	Version:	2
Date:	01-Nov-22		
Contaminant	Fluoranthene		
Target Concentration (C _T)	6.00E-06	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Fluoranthene
Target concentration	0.000006 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value
Water filled soil porosity θ_w	2.28E-01	fraction	Calculated
Air filled soil porosity θ_a	8.90E-02	fraction	Calculated
Bulk density of soil zone material ρ	1.90E+00	g/cm ³	Site measurement for made ground
Henry's Law constant H	6.29E-05	dimensionless	Literature value

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd		l/kg	Literature value
-------------------------------------	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil) foc	5.80E-02	fraction	Site measurement for made ground
Organic carbon partition coefficient Koc	1.82E+04	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species $K_{oc,n}$		l/kg	
Sorption coefficient for ionised species $K_{oc,i}$		l/kg	
pH value pH		pH units	
Acid dissociation constant pKa			
Fraction of organic carbon (in soil) foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 1.06E+03 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	6.33E-03	mg/kg	(for comparison with soil analyses)
	or		
	0.000006	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Fluoranthene**
0.000006 mg/l

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Infiltration	Inf	2.40E-04	m/d	Estimated based on 10% infiltration
Area of contaminant source	A	9.53E+02	m ²	Measurement based on mapping/observation
Not used in calculation				
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.20E+01	m	Measurement of source zone
Saturated aquifer thickness	da	3.00E+02	m	Literature value for Collyhurst Sandstone
Hydraulic Conductivity of aquifer in which dilution occurs	K	4.00E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.20E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	2.20E+01	m	Site measurement
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	Not used in calculation
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	6.48E+00	m	

Calculated Parameters

Dilution Factor	DF	7.64E+00	
Level 2 Remedial Target		4.59E-05	mg/l
		or	
		4.84E-02	mg/kg
For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.			
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water			

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Fluoranthene		from Level 1
Target Concentration	Cr	0.000006	mg/l	from Level 1
Dilution Factor	DF	7.64E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.90E+02	days	Howard, 1991
Calculated decay rate	2.39E-03	days ⁻¹	calculated
Width of plume in aquifer at source	2.20E+01	m	from Level 2
Plume thickness in aquifer at source	6.48E+00	m	from Level 2
Bulk density of aquifer materials	2.24E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.50E-01	fraction	Literature value
Hydraulic gradient	3.68E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	4.00E-01	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Distance to river from centre of gasworks
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.73E+01	l/kg see options
Longitudinal dispersivity	ax	5.000	m see options
Transverse dispersivity	az	0.500	m see options
Vertical dispersivity	ay	0.050	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	5.89E-02	m/d
Retardation factor	2.46E+02	fraction
Decay rate used	9.73E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	3.68E-02	fraction
Rate of contaminant flow due to retardation	2.40E-04	m/d
Ratio of Compliance Point to Source Concentration	C _{ED} /C ₀	fraction
Attenuation factor (C ₀ /C _{ED})	AF	6.43E+00

Remedial Targets

Level 3 Remedial Target	2.95E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	3.11E-01	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	50	m	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

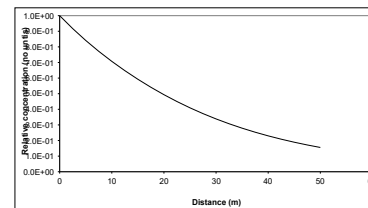
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	5.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	5.00E+00	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance Relative concentration

(No units)

0 1.0E+00

2.5 9.17E-01

5.0 8.41E-01

7.5 7.71E-01

10.0 7.07E-01

12.5 6.48E-01

15.0 5.93E-01

17.5 5.41E-01

20.0 4.94E-01

22.5 4.50E-01

25.0 4.09E-01

27.5 3.72E-01

30.0 3.38E-01

32.5 3.07E-01

35.0 2.79E-01

37.5 2.53E-01

40.0 2.30E-01

42.5 2.08E-01

45.0 1.89E-01

47.5 1.72E-01

50.0 1.56E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	2.28E-01	fraction
Air filled soil porosity	θ_a	8.90E-02	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	6.29E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg
Factor (partitioning between soil and water)		1.06E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

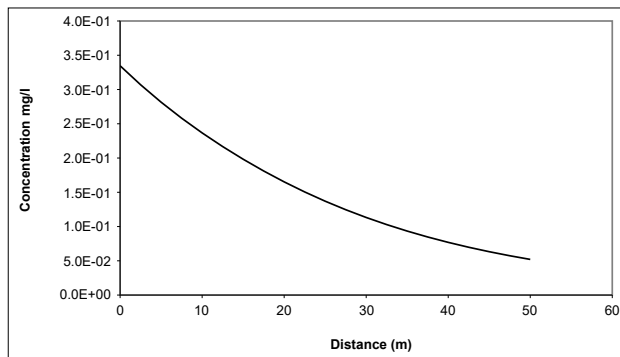
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.56E+00 mg/l	No dilution or attenuation
Level 2	C	3.35E-01 mg/l	Dilution taken into account
Level 3	C	5.20E-02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.35E-01
2.50	3.07E-01
5.00	2.81E-01
7.50	2.58E-01
10.00	2.37E-01
12.50	2.17E-01
15.00	1.98E-01
17.50	1.81E-01
20.00	1.65E-01
22.50	1.51E-01
25.00	1.37E-01
27.50	1.25E-01
30.00	1.13E-01
32.50	1.03E-01
35.00	9.34E-02
37.50	8.48E-02
40.00	7.69E-02
42.50	6.98E-02
45.00	6.33E-02
47.50	5.74E-02
50.00	5.20E-02

B.3 Re-use of site-won soils in St. Catherine’s Wood/Red Bank Terrace

B.3.1 Context

A regrading exercise is proposed within the HIF Infrastructure boundary to create the desired development platform levels and stable slopes. No general re-use criteria have been generated for the Red Bank Plateau area. The reason for this is that the future development plots are to be covered with buildings and hardstanding, and very little infiltration is anticipated through the made ground. Currently, the majority of the site is vegetated ground with little hardstanding and no enclosed surface water drainage system. The development is therefore expected to significantly reduce infiltration within the proposed development plots and the made ground is unlikely to pose a significant risk to controlled waters. The identified ‘sources’ of contamination within Red Bank Plateau (namely the gasworks and the carriage shed areas) are to receive targeted remediation, as discussed elsewhere in this document.

A limited amount of regrading is proposed within the St. Catherine’s Wood and Red Bank Terrace areas of the site, as shown in **Drawing 9**. These areas are to be public open space and parkland, where infiltration through the ground will not be prevented by surface water drainage. Much of the area is formed of steep slopes, which will remain following completion of the HIF Infrastructure scheme, which will promote runoff of surface water into the River Irk. The areas are also to be planted, which will reduce the amount of infiltration possible.

Material cut from Red Bank Terrace and St. Catherine’s Wood is expected to be moved within a short distance in the same setting i.e. material from Red Bank Terrace will be placed within Red Bank Terrace to regrade the existing slope. As material is generally being moved within a few metres within the same environmental setting, it is not anticipated to pose a risk to the water environment, as the available evidence suggests that the current site condition is not having a significant impact on the quality of the River Irk (discussed in **Section 4.4**).

There is a possibility that material from elsewhere within the Site boundary (termed ‘re-used material’ for the purposes of this report) might be used to make up a shortfall of material within the Red Bank Terrace or St. Catherine’s Wood areas. This re-used material would not have been sourced from the same area of the Site and will be placed closer to the River Irk, therefore has the potential to create a new risk to the water environment. It is therefore considered appropriate to generate re-use criteria for such material, to ensure no new environmental risks are introduced.

B.3.2 Exposure assumptions

Due to the proximity of Red Bank Terrace or St. Catherine’s Wood to the river, there is a shorter distance over which any dissolved contamination can attenuate before reaching the river compared to Red Bank Plateau. Based on the current understanding of the cut and fill requirements within the Site, such material may be placed within two zones: close to the River Irk (within 50m) and further away (a distance between 50m and 130m from the river). These zones are illustrated in **Drawing 9**.

Reuse criteria for materials placed within these zones have been developed for the contaminants of concern using the Environment Agency’s Remedial Targets Methodology (RTM) workbook⁵, assuming that the re-used material is the source. Input parameters and outputs from RTM are presented in the tables below and later in this Appendix.

The target concentrations chosen are identified in **Table 15** and are discussed in the previous section.

B.3.3 Level 1 soil parameters

A summary of the model parameters used in Level 1 is presented in **Table 16**.

⁵ Environment Agency (2006) Remedial Targets Methodology

⁶ <https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcqrqyr80>

B.3.3.1 Soil porosity

No site-specific data is available for the effective porosity of the soil source. However, this has been estimated based on the empirical relationship derived from the soil bulk density and moisture content.

B.3.3.2 Bulk density of soil zone

As the re-used material may be derived from anywhere within the HIF Infrastructure site, data relating to soil bulk density and moisture content have been used for made ground site-wide. Estimated bulk unit weight for the made ground generally is 18kN/m-3 (1.8g/cm) with a natural moisture content average of 21%.

Table 16 Summary of parameters used in Level 1 RTM

Parameter		Unit	Value used in Level 1 Assessment	Source
Bulk density of soil zone material	p	g/cm ³	1.8	Site measurement
Fraction of organic carbon (soil)	foc	-	0.058	Site measurement (made ground)
Moisture Content		%	21	Site measurement
Water filled soil porosity	□w	fraction	0.312	Calculated based on above parameters
Air filled soil porosity	□a	fraction	0.152	Calculated based on above parameters

B.3.4 Level 2 and 3 aquifer parameters

A summary of the Level 2 and 3 model parameters used to generate re-use criteria for Zones 1 and 2 are presented in **Table 17**.

B.3.4.1 Infiltration

The rainfall has been taken from Met Office data⁶ for the climate station at Woodford for the period 1991 to 2020. The annual average rainfall is 868.40mm/yr (0.0024m/d).

The St. Catherine’s Wood and Red Bank Terrace areas will be predominantly public open space, comprising slopes with access paths and planting. Some runoff is expected from the slopes and evapotranspiration from planting, but it is likely that a high proportion of the rainfall will infiltrate. The assumed infiltration rate in these areas is 60%. The calculated infiltration rate within the open space areas is therefore 0.0014m/d.

B.3.4.2 Hydraulic conductivity of aquifer in which dilution occurs

The re-used material may be placed either within St. Catherine’s Wood or Red Bank Terrace. There are two principal aquifers within the site boundary: the Collyhurst Sandstone and the Chester Pebble Beds. The proposed fill to public open space areas is over Manchester Marl and Chester Pebble Beds. Of these, the Chester Pebble Beds is taken to be the aquifer in which dilution occurs as this is likely to be providing some base flow to the River Irk. The use of the Chester Pebble Beds is considered to provide a conservative assessment of the potential groundwater impact.

No site-specific data is available for hydraulic conductivity within the bedrock aquifer. Published values⁷ for hydraulic conductivity within the Chester Pebble Beds range from 3.1x10⁻⁴- to 15 m/d, with a median of 1.5 and a geometric mean of 0.57m/d. Another source gives the hydraulic conductivity of the Chester Pebble Beds of the Manchester area as 0.5 to 5m/d [9].

⁷ Baseline Report Series: 8. The Permo-Triassic Sandstones of Manchester and East Cheshire. Groundwater systems and water quality commissioned report CR/03/265N. Technical Report NC/99/74/8. <https://nora.nerc.ac.uk/id/eprint/3573/1/CR03265N.pdf>

B.3.4.3 Hydraulic gradient of water table

The groundwater hydraulic gradient was calculated from the groundwater elevation measured on site during the spot monitoring rounds undertaken as part of the 2022 GI. Calculated hydraulic gradients in the Chester Pebble Beds are in the range 0.023 to 0.045. The mean of these values has been taken as the hydraulic gradient beneath the site.

B.3.4.4 Width of contaminant source perpendicular to groundwater flow

Zone 1 (river bank to 50m)

The areas of proposed fill within Zone 1 vary from location to location. Some small areas of fill are proposed close to the Irk, although the largest areas of fill placement are against existing slopes in Zone 2.

The width of the placed fill areas within Zone 1 ranges from 17 to 82m. A median width of 50m has been adopted for use in this assessment. The length parallel to groundwater flow ranges from 21 to 28m, with a median length of 25m, which has been used for this assessment.

Zone 2 (50m to 130m from river bank)

The width of the placed fill areas within Zone 2 ranges from 37 to 63m. A median width of 50m has been adopted for use in this assessment. The length parallel to groundwater flow ranges from 53 to 73m, with a median of 63m, which has been used for this assessment.

B.3.4.5 Mixing zone thickness

The Chester Pebble Beds extends to great depth (over 300m) however, the thickness of the mixing zone along the groundwater pathway is substantially less, given that groundwater is believed to discharge into the River Irk. This parameter has been calculated in the model.

B.3.4.6 Bulk density of aquifer materials

The average bulk unit weight value for the Chester Pebble Beds from ground investigation data is 21kN/m³, or 2.1g/cm³.

B.3.4.7 Aquifer effective porosity

No site-specific data is available for the effective porosity of the aquifer. Literature values [9] quote a porosity at outcrop within the Chester Pebble Beds of 20 to 30%.

Core porosity data for the Chester Pebble Beds is in the range 12.4 to 33.2% with a median of 23.5% and an arithmetic mean of 23.2% [9].

B.3.4.8 Aquifer fraction of organic carbon

No site-specific data is available for the fraction of organic carbon in the aquifer. Literature values [REF] quote a range for Permo-Triassic Sandstones between 0.00028 to 0.0015. A value of 0.0015 has been selected for use in the assessment.

B.3.4.9 Distance to compliance point

The distance to the compliance point (the River Irk) has been set at 25m for re-used materials placed in Zone 1, and 90m for re-used materials placed in Zone 2. These are the median distances for each zone.

Table 17 Summary of parameters used for Level 2 and 3 RTM, Zones 1 and 2

Parameter		Unit	Range	Value used in Assessment	Source
Effective Rainfall	E	m/d	0.0024	0.0024	Met Office data
Infiltration Factor		%	60	60	Assumption based on soft landscaping use
Infiltration rate	Inf	m/d	0.0014	0.0014	Calculated
Length of Zone 1 parallel to flow	L	m	21 to 28	25	Median of site measurement
Width of Zone 1 parallel to flow	W	m	17 to 82	50	Median of site measurement
Length of Zone 2 parallel to flow	L	m	53 to 73	63	Median of site measurement
Width of Zone 2 parallel to flow	W	m	37 to 63	50	Median of site measurement
Hydraulic conductivity of aquifer	K	m/d	3.1x10 ⁻⁴ to 15 Median: 1.5 Mean: 0.57	0.57	Literature value, geometric mean
Saturated aquifer thickness		m	150 to 1300	150	Minimum thickness of Chester Formation sandstone
Hydraulic Gradient	I	m/m	0.023 to 0.045	0.034	Site specific
Depth of Mixing	M _z	m	Base of aquifer not penetrated	Calculated	RTM
Bulk density of aquifer materials (sandstone)		g/cm ³	21kN/m ³	2.1	Site specific
Aquifer effective porosity		%	20 to 30% 12.4 to 33.2 Median 23.5 Mean 23.2	23.2	Literature value, arithmetic mean
Distance to compliance point (Zone 1)		m	0 to 50	25	Median distance within Zone 1
Distance to compliance point (Zone 2)		m	50	130	Median distance within Zone 2
Fraction of organic carbon in aquifer	foc	-	0.00028 to 0.0015	0.0015	Literature value for Permo-Triassic Sandstone, maximum

B.3.5 RTM targets for re-use

Table 18 and Table 19 below summarise the remediation criteria generated using RTM for the re-use of fill materials close to the river, which are designed to be protective of controlled waters.

Table 18 Target concentrations for the protection of controlled waters in re-used fill in Zone 1

Contaminant	Level 1 target (mg/kg)	Level 1 target (mg/l)	Level 2 target (mg/kg)	Level 2 target (mg/l)	Level 3 target (mg/kg)	Level 3 target (mg/l)
Chromium	27.4	0.01	93.5	0.02	93.5	0.02
Copper	14	0.03	48	0.1	48	0.1
Lead	3.72	0.004	12.9	0.01	12.9	0.01
Nickel	7.65	0.02	26.5	0.05	26.5	0.05
Zinc	55.90	0.11	191	0.38	191	0.38
Benzo(a)Pyrene	0.08	0.00001	0.26	0.00003	0.4	0.00006
Fluoranthene	0.01	0.00001	0.02	0.00002	0.04	0.00003
Anthracene	0.03	0.0001	0.11	0.0003	0.15	0.0005
TPH – Aliphatic C8-C10	559	0.3	1910	1.03	1910	1.03
TPH – Aliphatic C10-C12	4350	0.3	14900	1.03	14900	1.03
TPH – Aliphatic C12-C16	87000	0.3	297000	1.03	297000	1.03
TPH – Aromatic C8-C10	27.9	0.3	95.4	1.03	153	1.6
TPH – Aromatic C10-C12	13.1	0.09	44.7	0.31	76	0.5
TPH – Aromatic C12-C16	26.1	0.09	90.3	0.31	208	0.7
TPH – Aromatic C16-C21	83.5	0.09	289	0.31	323	0.3
TPH – Aromatic C21-C35	679	0.09	2350	0.31	2543	0.3

Table 19 Target concentrations for the protection of controlled waters in re-used fill in Zone 2

Contaminant	Level 1 target (mg/kg)	Level 1 target (mg/l)	Level 2 target (mg/kg)	Level 2 target (mg/l)	Level 3 target (mg/kg)	Level 3 target (mg/l)
Chromium	27.4	0.0057	93.3	0.0194	93.6	0.0195
Copper	14	0.028	47.9	0.0954	50.6	0.101
Lead	3.72	0.00372	12.8	0.0128	13.6	0.0136
Nickel	7.65	0.0153	26.4	0.0528	27.9	0.0558
Zinc	55.9	0.1115	191	0.380	191	0.382
Benzo(a)Pyrene	0.0754	0.00001	0.257	0.00003	1.4	0.0002
Fluoranthene	0.00633	0.000006	0.02	0.00002	0.11	0.0001
Anthracene	0.0326	0.0001	0.113	0.0003	0.34	0.0010
TPH – Aliphatic C8-C10	559	0.3	1900	1.02	2014	1.1
TPH – Aliphatic C10-C12	4350	0.3	14800	1.02	14900	1.0
TPH – Aliphatic C12-C16	87000	0.3	297000	1.02	313662	1.1
TPH – Aromatic C8-C10	27.9	0.3	95.1	1.02	470	5.1
TPH – Aromatic C10-C12	13.1	0.09	44.5	0.307	265	1.8
TPH – Aromatic C12-C16	2.61	0.09	90.1	0.31	1258	4.3
TPH – Aromatic C16-C21	83.5	0.09	288	0.31	449	0.5
TPH – Aromatic C21-C35	679	0.09	2340	0.31	3284	0.4



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	TPH - Aliphatic C8-C10		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C8-C10
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	8.20E+01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	3.20E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.86E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	5.59E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aliphatic C8-C10** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill in zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill in zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value for Chester Pebble Beds
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill in zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00		
Level 2 Remedial Target		1.03E+00 or 1.91E+03	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C8-C10		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.49E+00	m
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	4.80E+01	l/kg
Longitudinal dispersivity	ax	2.500	m
Transverse dispersivity	az	0.250	m
Vertical dispersivity	ay	0.025	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01	m/d
Retardation factor	R _f	4.39E+02	fraction
Decay rate used	λ	1.75E-103	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02	fraction
Rate of contaminant flow due to retardation	u	2.71E-04	m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.03E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 3.20E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow} l/kgSorption coefficient for ionised species K_{ow} l/kg

pH value pH

Acid dissociation constant pK_a l/kgFraction of organic carbon in aquifer f_{oc} fractionSoil water partition coefficient K_d 4.80E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

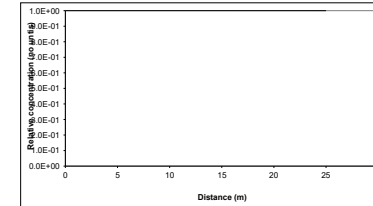
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	0.00E+00	2.50E-01	1.88E-01	m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.88E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	1.00E+00
2.5	1.00E+00
3.8	1.00E+00
5.0	1.00E+00
6.3	1.00E+00
7.5	1.00E+00
8.8	1.00E+00
10.0	1.00E+00
11.3	1.00E+00
12.5	1.00E+00
13.8	1.00E+00
15.0	1.00E+00
16.3	1.00E+00
17.5	1.00E+00
18.8	1.00E+00
20.0	1.00E+00
21.3	1.00E+00
22.5	1.00E+00
23.8	1.00E+00
25.0	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	8.20E+01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.86E+03	l/kg
Factor (partitioning between soil and water)		1.86E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

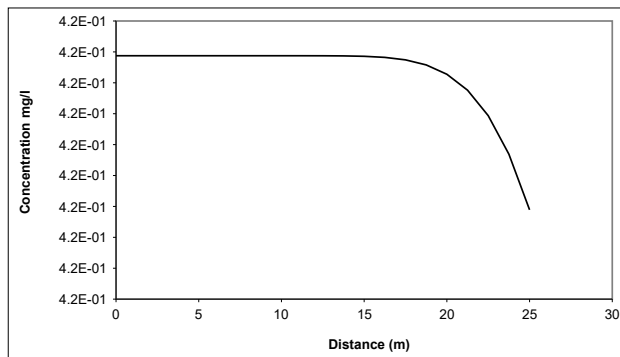
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.45E+00	mg/l	No dilution or attenuation
Level 2	C	4.24E-01	mg/l	Dilution taken into account
Level 3	C	4.24E-01	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	4.24E-01
1.25	4.24E-01
2.50	4.24E-01
3.75	4.24E-01
5.00	4.24E-01
6.25	4.24E-01
7.50	4.24E-01
8.75	4.24E-01
10.00	4.24E-01
11.25	4.24E-01
12.50	4.24E-01
13.75	4.24E-01
15.00	4.24E-01
16.25	4.24E-01
17.50	4.24E-01
18.75	4.24E-01
20.00	4.24E-01
21.25	4.24E-01
22.50	4.24E-01
23.75	4.24E-01
25.00	4.24E-01



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	TPH - Aliphatic C10-C12		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C10-C12
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.30E+02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	2.50E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.45E+04	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	4.35E+03	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **TPH - Aliphatic C10-C12** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill areas in Zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill areas in Zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value for Chester Pebble Beds
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00		
Level 2 Remedial Target		1.03E+00 or 1.49E+04	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C10-C12		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.49E+00	m
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	3.75E+02	l/kg
Longitudinal dispersivity	ax	1.863	m
Transverse dispersivity	az	0.186	m
Vertical dispersivity	ay	0.019	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01	m/d
Retardation factor	R _f	3.42E+03	fraction
Decay rate used	λ	2.25E-104	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02	fraction
Rate of contaminant flow due to retardation	u	3.48E-05	m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.03E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d

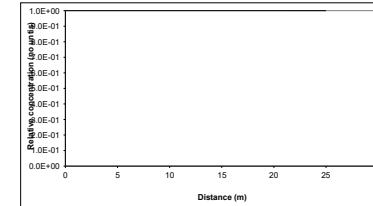
Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc}Organic carbon partition coefficient K_{oc}

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r}Sorption coefficient for ionised species K_{oc,i}

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc}Soil water partition coefficient K_d

Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration
From calculation sheet	(No units)
Distance	0
	1.0E+00
	1.3
	1.00E+00
	2.5
	1.00E+00
	3.8
	1.00E+00
	5.0
	1.00E+00
	6.3
	1.00E+00
	7.5
	1.00E+00
	8.8
	1.00E+00
	10.0
	1.00E+00
	11.3
	1.00E+00
	12.5
	1.00E+00
	13.8
	1.00E+00
	15.0
	1.00E+00
	16.3
	1.00E+00
	17.5
	1.00E+00
	18.8
	1.00E+00
	20.0
	1.00E+00
	21.3
	1.00E+00
	22.5
	1.00E+00
	23.8
	1.00E+00
	25.0
	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.30E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.45E+04	l/kg
Factor (partitioning between soil and water)		1.45E+04	dimensionless

Level 2 Parameters

Dilution Factor DF

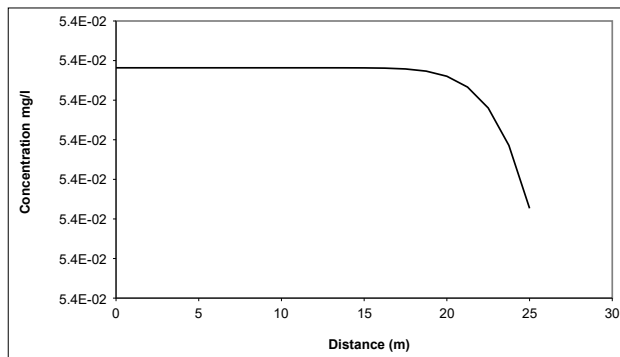
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.86E-01	mg/l	No dilution or attenuation
Level 2	C	5.44E-02	mg/l	Dilution taken into account
Level 3	C	5.44E-02	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	5.44E-02
1.25	5.44E-02
2.50	5.44E-02
3.75	5.44E-02
5.00	5.44E-02
6.25	5.44E-02
7.50	5.44E-02
8.75	5.44E-02
10.00	5.44E-02
11.25	5.44E-02
12.50	5.44E-02
13.75	5.44E-02
15.00	5.44E-02
16.25	5.44E-02
17.50	5.44E-02
18.75	5.44E-02
20.00	5.44E-02
21.25	5.44E-02
22.50	5.44E-02
23.75	5.44E-02
25.00	5.44E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	TPH - Aliphatic C12-C16		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C12-C16
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	5.40E+02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	5.00E+06	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	2.90E+05	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	8.70E+04	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **TPH - Aliphatic C12-C16** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimate based on 60% infiltration
	Area of contaminant source	A	1.33E+03	m ²	Median of fill areas in Zone 1 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill areas in Zone 1
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value for Chester Pebble Beds
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 1 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00		
Level 2 Remedial Target		1.03E+00 or 2.97E+05	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C12-C16		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.49E+00	m
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	7.50E+03	l/kg
Longitudinal dispersivity	ax	2.500	m
Transverse dispersivity	az	0.250	m
Vertical dispersivity	ay	0.025	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01	m/d
Retardation factor	R _f	6.85E+04	fraction
Decay rate used	λ	1.12E-105	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02	fraction
Rate of contaminant flow due to retardation	u	1.74E-06	m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.03E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	2.97E+05	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 5.00E+06 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow} l/kgSorption coefficient for ionised species K_{ow} l/kg

pH value pH l/kg

Acid dissociation constant pK_a l/kgFraction of organic carbon in aquifer f_{oc} fractionSoil water partition coefficient K_d 7.50E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

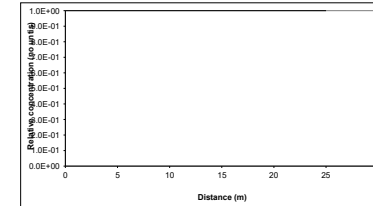
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	0.00E+00	2.50E+00
Transverse dispersivity	az	0.00E+00	2.50E-01
Vertical dispersivity	ay	0.00E+00	2.50E-02

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	1.00E+00
2.5	1.00E+00
3.8	1.00E+00
5.0	1.00E+00
6.3	1.00E+00
7.5	1.00E+00
8.8	1.00E+00
10.0	1.00E+00
11.3	1.00E+00
12.5	1.00E+00
13.8	1.00E+00
15.0	1.00E+00
16.3	1.00E+00
17.5	1.00E+00
18.8	1.00E+00
20.0	1.00E+00
21.3	1.00E+00
22.5	1.00E+00
23.8	1.00E+00
25.0	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	5.40E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	2.90E+05	l/kg
Factor (partitioning between soil and water)		2.90E+05	dimensionless

Level 2 Parameters

Dilution Factor DF

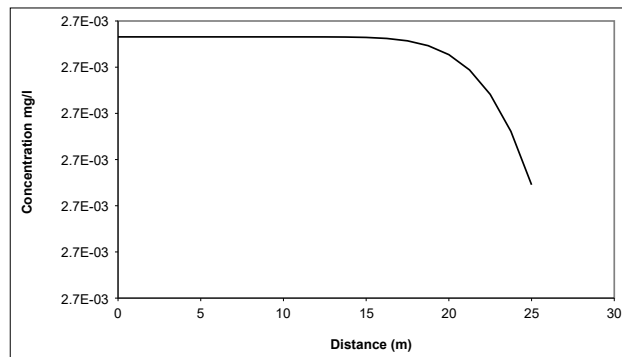
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	9.31E-03	mg/l	No dilution or attenuation
Level 2	C	2.72E-03	mg/l	Dilution taken into account
Level 3	C	2.72E-03	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.72E-03
1.25	2.72E-03
2.50	2.72E-03
3.75	2.72E-03
5.00	2.72E-03
6.25	2.72E-03
7.50	2.72E-03
8.75	2.72E-03
10.00	2.72E-03
11.25	2.72E-03
12.50	2.72E-03
13.75	2.72E-03
15.00	2.72E-03
16.25	2.72E-03
17.50	2.72E-03
18.75	2.72E-03
20.00	2.72E-03
21.25	2.72E-03
22.50	2.72E-03
23.75	2.72E-03
25.00	2.72E-03



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	Anthracene		
Target Concentration (C _T)	1.00E-04	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Anthracene
0.0001 mg/l

Input Parameters Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.12E-01

fraction

Calculated

Air filled soil porosity

θ_a

1.52E-01

fraction

Calculated

Bulk density of soil zone material

ρ

1.80E+00

g/cm³

Site measurement for made ground

Henry's Law constant

H

1.81E-04

dimensionless

Literature value

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Literature value

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

5.80E-02

fraction

Site measurement for made ground

Organic carbon partition coefficient

K_{oc}

5.62E+03

l/kg

Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

3.26E+02

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

3.26E-02

mg/kg

(for comparison with soil analyses)

or

0.0001

mg/l

(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works

Completed by: DH

Date: 01-Nov-22

Version: 3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Anthracene
0.0001

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill in zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill in zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill in zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.44E+00	m	

Calculated Parameters

Dilution Factor	DF	3.46E+00
Level 2 Remedial Target		3.46E-04 or 1.13E-01
		mg/l mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Anthraxene		from Level 1
Target Concentration	Cr	0.0001	mg/l	from Level 1
Dilution Factor	DF	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	4.60E+02	days Howard, 1991
Calculated decay rate	λ	1.51E-03	days ⁻¹ calculated
Width of plume in aquifer at source	Sz	5.00E+01	m from Level 2
Plume thickness in aquifer at source	Sy	4.44E+00	m from Level 2
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³ Site measurement
Effective porosity of aquifer	n	2.30E-01	fraction Literature value
Hydraulic gradient	i	4.78E-02	fraction from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d from Level 2
Distance to compliance point	x	2.50E+01	m Median of Zone 1
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.73E+01	l/kg see options
Longitudinal dispersivity	ax	2.500	m see options
Transverse dispersivity	az	0.250	m see options
Vertical dispersivity	ay	0.025	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	2.50E+02 fraction
Decay rate used	λ	6.02E-06 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.78E-02 fraction
Rate of contaminant flow due to retardation	u	4.74E-04 m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	7.35E-01 fraction
Attenuation factor (C ₀ /C ₁₀)	AF	1.36E+00 fraction

Remedial Targets

Level 3 Remedial Target	4.71E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	7.35E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

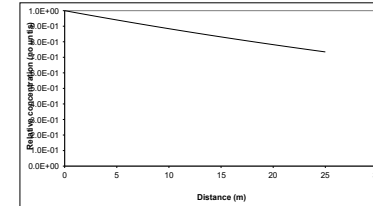
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	2.50E+00	2.50E+00	m
Transverse dispersivity	az	0.00E+00	2.50E-01	1.86E-01 m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.86E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	9.85E-01
2.5	9.70E-01
3.8	9.55E-01
5.0	9.40E-01
6.3	9.26E-01
7.5	9.12E-01
8.8	8.98E-01
10.0	8.84E-01
11.3	8.70E-01
12.5	8.57E-01
13.8	8.44E-01
15.0	8.31E-01
16.3	8.18E-01
17.5	8.06E-01
18.8	7.94E-01
20.0	7.81E-01
21.3	7.69E-01
22.5	7.58E-01
23.8	7.46E-01
25.0	7.35E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 2.70E+03 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.81E-04	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.26E+02	l/kg
Factor (partitioning between soil and water)		3.26E+02	dimensionless

Level 2 Parameters

Dilution Factor DF 3.46E+00

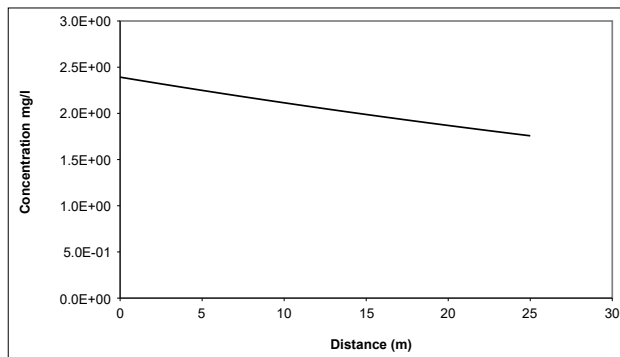
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF 1.36E+00

Predicted concentrations at compliance point

Level 1	C	8.27E+00 mg/l	No dilution or attenuation
Level 2	C	2.39E+00 mg/l	Dilution taken into account
Level 3	C	1.76E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.39E+00
1.25	2.36E+00
2.50	2.32E+00
3.75	2.28E+00
5.00	2.25E+00
6.25	2.21E+00
7.50	2.18E+00
8.75	2.15E+00
10.00	2.11E+00
11.25	2.08E+00
12.50	2.05E+00
13.75	2.02E+00
15.00	1.99E+00
16.25	1.96E+00
17.50	1.93E+00
18.75	1.90E+00
20.00	1.87E+00
21.25	1.84E+00
22.50	1.81E+00
23.75	1.78E+00
25.00	1.76E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C8-C10		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C8-C10
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	4.90E-01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.60E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	9.28E+01	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	2.79E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C8-C10** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	1.33E+03	m ²	Median of fill areas in Zone 1 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill areas in Zone 1
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Median of fill areas in Zone 1
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Site measurement Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00	
Level 2 Remedial Target		1.03E+00 or 9.54E+01	mg/l mg/kg
For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.			
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water			

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C8-C10		from Level 1
Target Concentration	0.3	mg/l	from Level 1
Dilution Factor	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.94E+02	days	Howard, 1991
Calculated decay rate	2.36E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	4.49E+00	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	2.50E+01	m	Median within Zone 1
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.40E+00	l/kg	see options
Longitudinal dispersivity	2.500	m	see options
Transverse dispersivity	0.250	m	see options
Vertical dispersivity	0.025	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	2.29E+01	fraction
Decay rate used	1.03E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.81E-02	fraction
Rate of contaminant flow due to retardation	5.20E-03	m/d
Ratio of Compliance Point to Source Concentration	6.23E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.60E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.64E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	1.53E+02	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	25	m	Ogata Banks
Ratio of Compliance Point to Source Concentration	C ₀ /C ₀	6.23E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.60E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.40E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

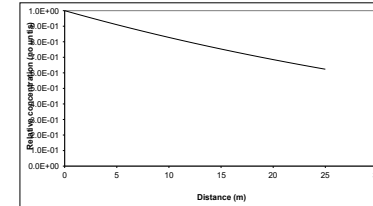
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	2.50E+00	0.00E+00 m
Transverse dispersivity	az	0.00E+00	2.50E-01	1.86E-01 m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.86E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	9.77E-01
2.5	9.54E-01
3.8	9.32E-01
5.0	9.10E-01
6.3	8.89E-01
7.5	8.68E-01
8.8	8.48E-01
10.0	8.28E-01
11.3	8.08E-01
12.5	7.90E-01
13.8	7.71E-01
15.0	7.53E-01
16.3	7.36E-01
17.5	7.18E-01
18.8	7.02E-01
20.0	6.85E-01
21.3	6.69E-01
22.5	6.54E-01
23.8	6.38E-01
25.0	6.23E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	4.90E-01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.28E+01	l/kg
Factor (partitioning between soil and water)		9.30E+01	dimensionless

Level 2 Parameters

Dilution Factor DF

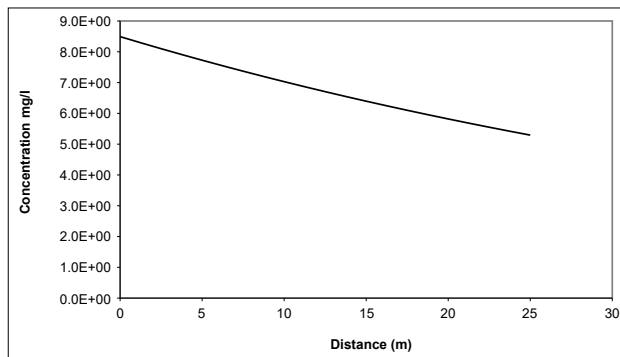
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.90E+01 mg/l	No dilution or attenuation
Level 2	C	8.49E+00 mg/l	Dilution taken into account
Level 3	C	5.29E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	8.49E+00
1.25	8.29E+00
2.50	8.10E+00
3.75	7.91E+00
5.00	7.73E+00
6.25	7.55E+00
7.50	7.37E+00
8.75	7.20E+00
10.00	7.03E+00
11.25	6.87E+00
12.50	6.71E+00
13.75	6.55E+00
15.00	6.40E+00
16.25	6.25E+00
17.50	6.10E+00
18.75	5.96E+00
20.00	5.82E+00
21.25	5.68E+00
22.50	5.55E+00
23.75	5.42E+00
25.00	5.29E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C10-C12		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C10-C12
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.40E-01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	2.50E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.45E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	1.31E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C10-C12** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill within Zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill within Zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill within Zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00		
Level 2 Remedial Target		3.08E-01 or 4.47E+01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C10-C12		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.58E+02	days	Howard, 1991
Calculated decay rate	2.69E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	4.49E+00	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	2.50E+01	m	Median distance within Zone 1
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	3.75E+00	l/kg	see options
Longitudinal dispersivity	2.500	m	see options
Transverse dispersivity	0.250	m	see options
Vertical dispersivity	0.025	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable		
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	3.52E+01	fraction
Decay rate used	7.62E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.81E-02	fraction
Rate of contaminant flow due to retardation	3.38E-03	m/d
Ratio of Compliance Point to Source Concentration	5.85E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.71E+00	fraction

Remedial Targets

Level 3 Remedial Target	5.25E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	7.63E+01	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₀	5.85E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 2.50E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 3.75E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

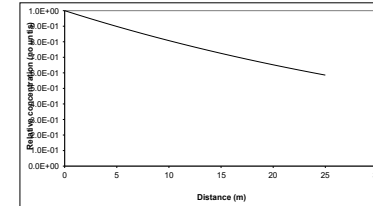
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	
Transverse dispersivity	az	0.00E+00	2.50E-01	1.86E-01	m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.86E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	9.74E-01
2.5	9.48E-01
3.8	9.23E-01
5.0	8.98E-01
6.3	8.75E-01
7.5	8.52E-01
8.8	8.29E-01
10.0	8.07E-01
11.3	7.86E-01
12.5	7.65E-01
13.8	7.45E-01
15.0	7.25E-01
16.3	7.06E-01
17.5	6.88E-01
18.8	6.69E-01
20.0	6.52E-01
21.3	6.34E-01
22.5	6.18E-01
23.8	6.01E-01
25.0	5.85E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 2.70E+03 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.40E-01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.45E+02	l/kg
Factor (partitioning between soil and water)		1.45E+02	dimensionless

Level 2 Parameters

Dilution Factor DF 3.42E+00

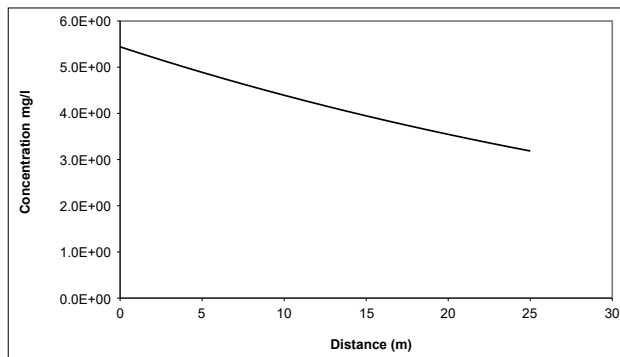
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF 1.71E+00

Predicted concentrations at compliance point

Level 1	C	1.86E+01 mg/l	No dilution or attenuation
Level 2	C	5.44E+00 mg/l	Dilution taken into account
Level 3	C	3.19E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	5.44E+00
1.25	5.30E+00
2.50	5.16E+00
3.75	5.02E+00
5.00	4.89E+00
6.25	4.76E+00
7.50	4.63E+00
8.75	4.51E+00
10.00	4.39E+00
11.25	4.28E+00
12.50	4.16E+00
13.75	4.05E+00
15.00	3.95E+00
16.25	3.84E+00
17.50	3.74E+00
18.75	3.64E+00
20.00	3.55E+00
21.25	3.45E+00
22.50	3.36E+00
23.75	3.27E+00
25.00	3.19E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C12-C16		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C12-C16
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	5.40E-02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	5.00E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	2.90E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	2.61E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C12-C16** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill areas within Zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill areas within Zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas within Zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.44E+00	m	

Calculated Parameters

Dilution Factor	DF	3.46E+00		
Level 2 Remedial Target		3.11E-01 or 9.03E+01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C12-C16		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks

Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.62E+02	days	Howard, 1991
Calculated decay rate	4.28E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	4.44E+00	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.78E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	2.50E+01	m	Median distance within Zone 1
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	7.50E+00	l/kg	see options
Longitudinal dispersivity	2.500	m	see options
Transverse dispersivity	0.250	m	see options
Vertical dispersivity	0.025	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	6.95E+01	fraction
Decay rate used	6.16E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.78E-02	fraction
Rate of contaminant flow due to retardation	1.71E-03	m/d
Ratio of Compliance Point to Source Concentration	4.35E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	2.30E+00	fraction

Remedial Targets

Level 3 Remedial Target	7.16E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	2.08E+02	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₀	4.35E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 5.00E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 7.50E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

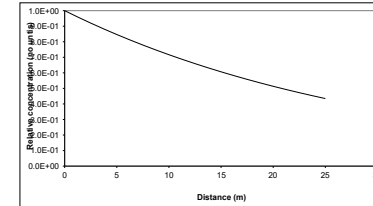
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	2.50E+00	0.025E+00	m
Transverse dispersivity	az	0.00E+00	2.50E-01	1.86E-01 m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.86E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	9.59E-01
2.5	9.20E-01
3.8	8.83E-01
5.0	8.47E-01
6.3	8.12E-01
7.5	7.79E-01
8.8	7.47E-01
10.0	7.17E-01
11.3	6.87E-01
12.5	6.59E-01
13.8	6.32E-01
15.0	6.07E-01
16.3	5.82E-01
17.5	5.58E-01
18.8	5.35E-01
20.0	5.14E-01
21.3	4.93E-01
22.5	4.72E-01
23.8	4.53E-01
25.0	4.35E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	5.40E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	2.90E+02	l/kg
Factor (partitioning between soil and water)		2.90E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

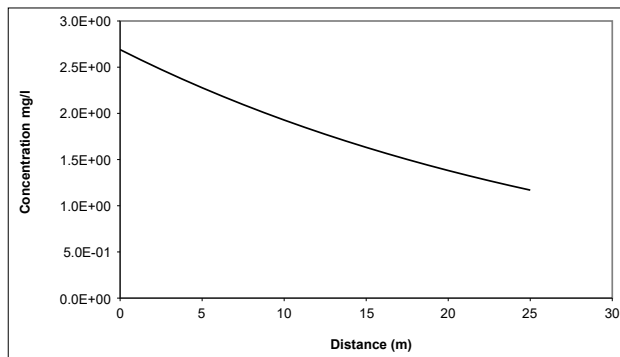
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	9.30E+00 mg/l	No dilution or attenuation
Level 2	C	2.69E+00 mg/l	Dilution taken into account
Level 3	C	1.17E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.69E+00
1.25	2.58E+00
2.50	2.47E+00
3.75	2.37E+00
5.00	2.28E+00
6.25	2.18E+00
7.50	2.10E+00
8.75	2.01E+00
10.00	1.93E+00
11.25	1.85E+00
12.50	1.77E+00
13.75	1.70E+00
15.00	1.63E+00
16.25	1.57E+00
17.50	1.50E+00
18.75	1.44E+00
20.00	1.38E+00
21.25	1.32E+00
22.50	1.27E+00
23.75	1.22E+00
25.00	1.17E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C16-C21		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration
C_T

TPH - Aromatic C16-C21
0.09 mg/l

Input Parameters Standard entry

Variable Value Unit Source of parameter value

Water filled soil porosity θ_w 3.12E-01 fraction
Air filled soil porosity θ_a 1.52E-01 fraction
Bulk density of soil zone material ρ 1.80E+00 g/cm³
Henry's Law constant H 1.30E-02 dimensionless

Calculated
Calculated
Site measurement for made ground
Literature value

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d Literature value

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc} 5.80E-02 fraction

Organic carbon partition coefficient

K_{oc} 1.60E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n} l/kg

Sorption coefficient for ionised species

K_{oc,i} l/kg

pH value

pH pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc} fraction

Soil water partition coefficient used in Level Assessment K_d 9.28E+02 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	8.35E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C16-C21** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median value for fill in Zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median value for fill in Zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median value for fill in Zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.44E+00	m	

Calculated Parameters

Dilution Factor	DF	3.46E+00		
Level 2 Remedial Target		3.11E-01 or 2.89E+02	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C16-C21		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.31E+03	days	Howard 1991
Calculated decay rate	5.29E-04	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	4.44E+00	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.78E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	2.50E+01	m	Median distance in Zone 1
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.40E+01	l/kg	see options
Longitudinal dispersivity	2.500	m	see options
Transverse dispersivity	0.250	m	see options
Vertical dispersivity	0.025	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	2.20E+02	fraction
Decay rate used	2.40E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.78E-02	fraction
Rate of contaminant flow due to retardation	5.38E-04	m/d
Ratio of Compliance Point to Source Concentration	8.95E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.12E+00	fraction

Remedial Targets

Level 3 Remedial Target	3.48E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	3.23E+02	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	8.95E-01	fraction	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.80E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.40E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

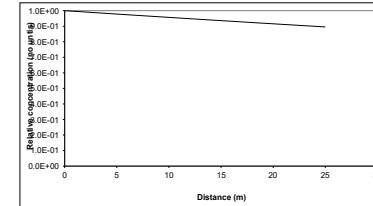
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	2.50E+00	0.02E+00	m
Transverse dispersivity	az	0.00E+00	2.50E-01	m
Vertical dispersivity	ay	0.00E+00	2.50E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	9.94E-01
2.5	9.89E-01
3.8	9.84E-01
5.0	9.78E-01
6.3	9.73E-01
7.5	9.67E-01
8.8	9.62E-01
10.0	9.57E-01
11.3	9.52E-01
12.5	9.46E-01
13.8	9.41E-01
15.0	9.36E-01
16.3	9.31E-01
17.5	9.26E-01
18.8	9.21E-01
20.0	9.15E-01
21.3	9.10E-01
22.5	9.05E-01
23.8	9.00E-01
25.0	8.95E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.28E+02	l/kg
Factor (partitioning between soil and water)		9.28E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

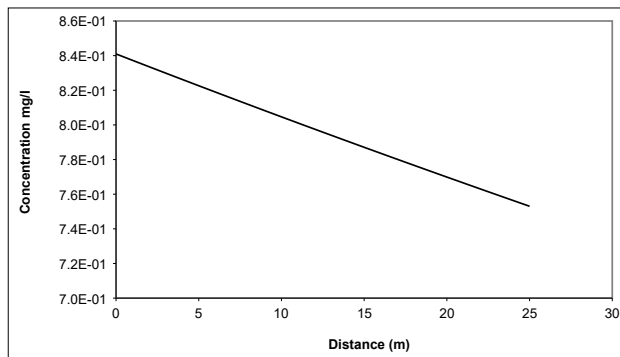
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.91E+00 mg/l	No dilution or attenuation
Level 2	C	8.41E-01 mg/l	Dilution taken into account
Level 3	C	7.53E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	8.41E-01
1.25	8.36E-01
2.50	8.32E-01
3.75	8.27E-01
5.00	8.23E-01
6.25	8.18E-01
7.50	8.14E-01
8.75	8.09E-01
10.00	8.05E-01
11.25	8.00E-01
12.50	7.96E-01
13.75	7.91E-01
15.00	7.87E-01
16.25	7.83E-01
17.50	7.78E-01
18.75	7.74E-01
20.00	7.70E-01
21.25	7.66E-01
22.50	7.61E-01
23.75	7.57E-01
25.00	7.53E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	TPH - Aromatic C21-C35		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C21-C35
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.80E-04	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.79E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C21-C35** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill within Zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill within Zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill within Zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.44E+00	m	

Calculated Parameters

Dilution Factor	DF	3.46E+00		
Level 2 Remedial Target		3.11E-01 or 2.35E+03	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C21-C35		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.81E+03	days	Howard, 1991
Calculated decay rate	3.82E-04	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	4.44E+00	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.78E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	2.50E+01	m	Median distance within zone 1
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	2.500	m	see options
Transverse dispersivity	0.250	m	see options
Vertical dispersivity	0.025	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable		
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	1.78E+03 fraction
Decay rate used	λ	2.15E-07 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.78E-02 fraction
Rate of contaminant flow due to retardation	u	6.65E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{EO} /C ₀	9.23E-01 fraction
Attenuation factor (C ₀ /C _{EO})	AF	1.08E+00 fraction

Remedial Targets

Level 3 Remedial Target	3.37E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EO} /C ₀	9.23E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

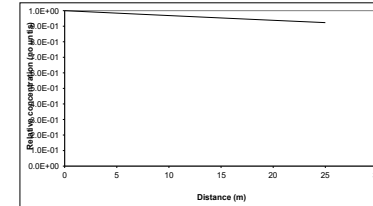
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	2.50E+00	0.25E+00 m
Transverse dispersivity	az	0.00E+00	2.50E-01 m
Vertical dispersivity	ay	0.00E+00	2.50E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	9.96E-01
2.5	9.92E-01
3.8	9.88E-01
5.0	9.84E-01
6.3	9.80E-01
7.5	9.76E-01
8.8	9.72E-01
10.0	9.69E-01
11.3	9.65E-01
12.5	9.61E-01
13.8	9.57E-01
15.0	9.53E-01
16.3	9.49E-01
17.5	9.46E-01
18.8	9.42E-01
20.0	9.38E-01
21.3	9.34E-01
22.5	9.31E-01
23.8	9.27E-01
25.0	9.23E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	6.80E-04	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

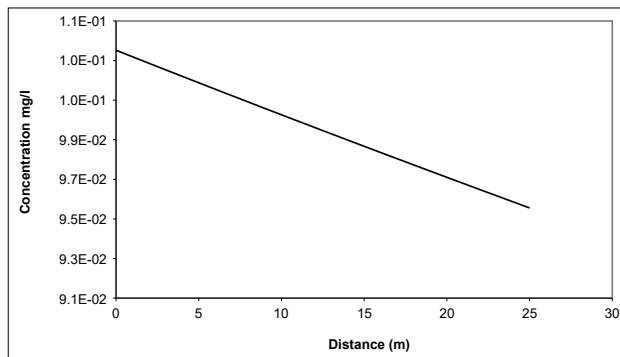
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	3.58E-01 mg/l	No dilution or attenuation
Level 2	C	1.04E-01 mg/l	Dilution taken into account
Level 3	C	9.56E-02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.04E-01
1.25	1.03E-01
2.50	1.03E-01
3.75	1.02E-01
5.00	1.02E-01
6.25	1.01E-01
7.50	1.01E-01
8.75	1.01E-01
10.00	1.00E-01
11.25	9.99E-02
12.50	9.95E-02
13.75	9.91E-02
15.00	9.87E-02
16.25	9.83E-02
17.50	9.79E-02
18.75	9.75E-02
20.00	9.71E-02
21.25	9.67E-02
22.50	9.63E-02
23.75	9.59E-02
25.00	9.56E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	Benzo(a)Pyrene		
Target Concentration (C _T)	1.00E-05	mg/l	Origin of C _T : Background concentration in Irk

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Benzo(a)Pyrene
Target concentration	0.00001 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	1.92E-05	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg	Literature value
----------------------------------	----	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc	0.058	fraction	Site measurement for made ground
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 7.54E+03 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	7.54E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.00001	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Benzo(a)Pyrene** from Level 1
0.00001 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Calculated assuming 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median area of fill in zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median length of fill areas zone 1
Saturated aquifer thickness	da	1.50E+02	m	Minimum thickness of Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Geometric mean for Chester Formation
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median width of fill in zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00		
Level 2 Remedial Target		3.42E-05 or 2.58E-01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzo(a)Pyrene		from Level 1
Target Concentration	Cr	0.00001	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.06E+03	days	Howard, 1991
Calculated decay rate	6.54E-04	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	4.49E+00	m	from Level 2
Bulk density of aquifer materials	2.12E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.32E-01	fraction	Literature value
Hydraulic gradient	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	2.50E+01	m	Median distance within Zone 1
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	1.863	m	see options
Transverse dispersivity	0.186	m	see options
Vertical dispersivity	0.019	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.18E-01	m/d
Retardation factor	1.78E+03	fraction
Decay rate used	3.67E-07	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.81E-02	fraction
Rate of contaminant flow due to retardation	6.62E-05	m/d
Ratio of Compliance Point to Source Concentration	8.72E-01	fraction
Attenuation factor (C ₀ /C ₁₀)	1.15E+00	fraction

Remedial Targets

Level 3 Remedial Target	3.92E-05	mg/l	For comparison with measured pore water concentration.
Ogata Banks	2.96E-01	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀	8.72E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

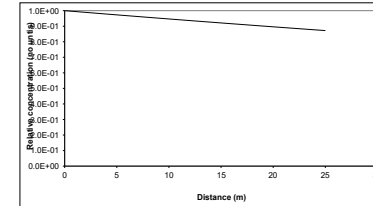
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	9.00E+00	2.50E+00 1.86E+00 m
Transverse dispersivity	az	9.00E+00	2.50E+01 1.86E-01 m
Vertical dispersivity	ay	9.00E+00	2.50E+02 1.86E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	9.93E-01
2.5	9.86E-01
3.8	9.80E-01
5.0	9.73E-01
6.3	9.66E-01
7.5	9.60E-01
8.8	9.53E-01
10.0	9.47E-01
11.3	9.40E-01
12.5	9.34E-01
13.8	9.27E-01
15.0	9.21E-01
16.3	9.15E-01
17.5	9.09E-01
18.8	9.02E-01
20.0	8.96E-01
21.3	8.90E-01
22.5	8.84E-01
23.8	8.78E-01
25.0	8.72E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.92E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

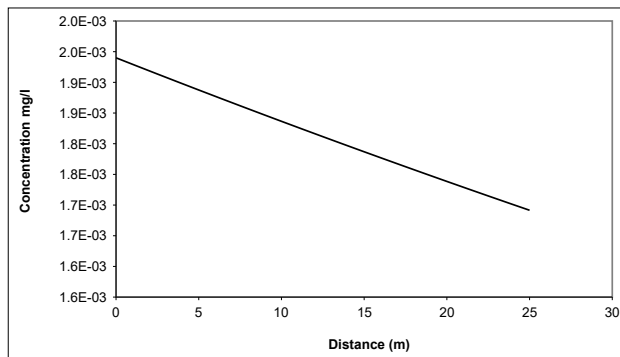
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	6.63E-03	mg/l	No dilution or attenuation
Level 2	C	1.94E-03	mg/l	Dilution taken into account
Level 3	C	1.69E-03	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.94E-03
1.25	1.93E-03
2.50	1.91E-03
3.75	1.90E-03
5.00	1.89E-03
6.25	1.87E-03
7.50	1.86E-03
8.75	1.85E-03
10.00	1.84E-03
11.25	1.82E-03
12.50	1.81E-03
13.75	1.80E-03
15.00	1.79E-03
16.25	1.77E-03
17.50	1.76E-03
18.75	1.75E-03
20.00	1.74E-03
21.25	1.73E-03
22.50	1.71E-03
23.75	1.70E-03
25.00	1.69E-03



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	Chromium		
Target Concentration (C _T)	0.0057	mg/l	Origin of C _T : BGS background concentration, 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Chromium
Target concentration	0.0057 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80	g/cm ³	Site measurement for made ground	
Henry's Law constant	0.00	dimensionless	N/A	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	4.80E+03	l/kg	Literature value
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Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 4.80E+03 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	2.74E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.0057	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Chromium
0.0057

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	1.33E+03	m ²	Median area of fill in Zone 1 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median length of fill in Zone 1
	Saturated aquifer thickness	da	1.50E+02	m	Minimum thickness of Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median width of fill in Zone 1 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00
Level 2 Remedial Target		1.95E-02 mg/l or 9.35E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Chromium		from Level 1
Target Concentration	C _r	0.0057	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.49E+00	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.32E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	Kd	4.80E+03	l/kg
Longitudinal dispersivity	ax	1.863	m
Transverse dispersivity	az	0.186	m
Vertical dispersivity	ay	0.019	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.18E-01 m/d
Retardation factor	Rf	4.39E+04
Decay rate used	λ	1.76E-105 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	2.69E-06 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00

Remedial Targets

Level 3 Remedial Target	1.95E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 4.80E+03 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc

Organic carbon partition coefficient Koc

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r}Sorption coefficient for ionised species K_{oc,i}

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 4.80E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

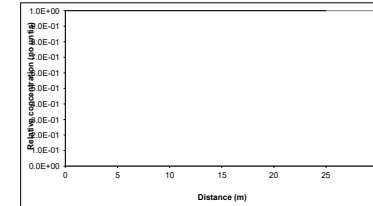
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	1.86E+00	1.86E+00 m
Transverse dispersivity	az	0.00E+00	1.86E-01 m
Vertical dispersivity	ay	0.00E+00	1.86E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	1.00E+00
2.5	1.00E+00
3.8	1.00E+00
5.0	1.00E+00
6.3	1.00E+00
7.5	1.00E+00
8.8	1.00E+00
10.0	1.00E+00
11.3	1.00E+00
12.5	1.00E+00
13.8	1.00E+00
15.0	1.00E+00
16.3	1.00E+00
17.5	1.00E+00
18.8	1.00E+00
20.0	1.00E+00
21.3	1.00E+00
22.5	1.00E+00
23.8	1.00E+00
25.0	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	4.80E+03	l/kg
Factor (partitioning between soil and water)		4.80E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

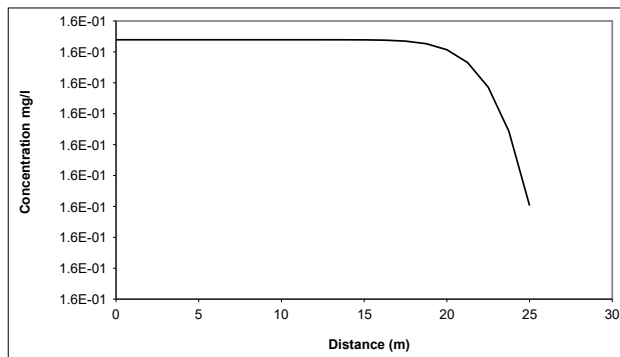
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.62E-01	mg/l	No dilution or attenuation
Level 2	C	1.65E-01	mg/l	Dilution taken into account
Level 3	C	1.65E-01	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.65E-01
1.25	1.65E-01
2.50	1.65E-01
3.75	1.65E-01
5.00	1.65E-01
6.25	1.65E-01
7.50	1.65E-01
8.75	1.65E-01
10.00	1.65E-01
11.25	1.65E-01
12.50	1.65E-01
13.75	1.65E-01
15.00	1.65E-01
16.25	1.65E-01
17.50	1.65E-01
18.75	1.65E-01
20.00	1.65E-01
21.25	1.65E-01
22.50	1.65E-01
23.75	1.65E-01
25.00	1.65E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	Copper		
Target Concentration (C _T)	0.028	mg/l	Origin of C _T : BGS background concentration, 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Copper
Target concentration	0.028 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value
Water filled soil porosity θ_w	3.12E-01	fraction	Calculated
Air filled soil porosity θ_a	1.52E-01	fraction	Calculated
Bulk density of soil zone material ρ	1.80E+00	g/cm ³	Site measurement for made ground
Henry's Law constant H	0.00E+00	dimensionless	N/A

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	5.01E+02	l/kg	Literature value
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Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 5.01E+02 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	1.40E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.028	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T

Copper
0.028 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	1.33E+03	m ²	Median of fill areas in Zone 1 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill areas in Zone 1
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 1 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	4.49E+00	m	

Calculated Parameters

Dilution Factor	DF	3.42E+00
Level 2 Remedial Target		9.57E-02 mg/l or 4.80E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Copper		from Level 1
Target Concentration	C _r	0.028	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.49E+00	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	5.01E+02	l/kg
Longitudinal dispersivity	ax	2.500	m
Transverse dispersivity	az	0.250	m
Vertical dispersivity	ay	0.025	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01	m/d
Retardation factor	R _f	4.62E+03	fraction
Decay rate used	λ	1.67E-104	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02	fraction
Rate of contaminant flow due to retardation	u	2.58E-05	m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00	fraction

Remedial Targets

Level 3 Remedial Target	9.57E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or	4.80E+01	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d 5.01E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc}Organic carbon partition coefficient K_{oc}

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r}Sorption coefficient for ionised species K_{oc,i}

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc}Soil water partition coefficient K_d 5.01E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

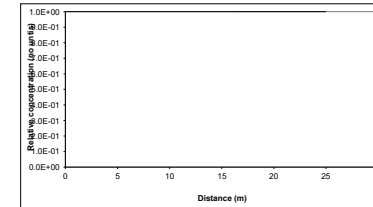
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	2.50E+00	2.50E+00	m
Transverse dispersivity	az	0.00E+00	2.50E-01	m
Vertical dispersivity	ay	0.00E+00	2.50E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration
From calculation sheet	(No units)
Distance	0
	1.0E+00
	1.3
	1.00E+00
	2.5
	1.00E+00
	3.8
	1.00E+00
	5.0
	1.00E+00
	6.3
	1.00E+00
	7.5
	1.00E+00
	8.8
	1.00E+00
	10.0
	1.00E+00
	11.3
	1.00E+00
	12.5
	1.00E+00
	13.8
	1.00E+00
	15.0
	1.00E+00
	16.3
	1.00E+00
	17.5
	1.00E+00
	18.8
	1.00E+00
	20.0
	1.00E+00
	21.3
	1.00E+00
	22.5
	1.00E+00
	23.8
	1.00E+00
	25.0
	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	5.01E+02	l/kg
Factor (partitioning between soil and water)		5.01E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

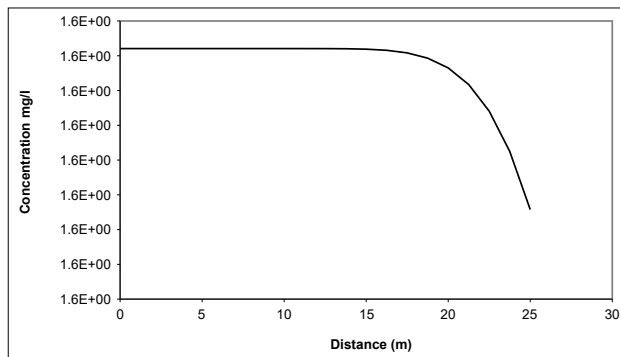
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.39E+00 mg/l	No dilution or attenuation
Level 2	C	1.58E+00 mg/l	Dilution taken into account
Level 3	C	1.58E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.58E+00
1.25	1.58E+00
2.50	1.58E+00
3.75	1.58E+00
5.00	1.58E+00
6.25	1.58E+00
7.50	1.58E+00
8.75	1.58E+00
10.00	1.58E+00
11.25	1.58E+00
12.50	1.58E+00
13.75	1.58E+00
15.00	1.58E+00
16.25	1.58E+00
17.50	1.58E+00
18.75	1.58E+00
20.00	1.58E+00
21.25	1.58E+00
22.50	1.58E+00
23.75	1.58E+00
25.00	1.58E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	Fluoranthene		
Target Concentration (C _T)	6.00E-06	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Fluoranthene
Target concentration	0.000006 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.29E-05	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.82E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.33E-03	mg/kg	(for comparison with soil analyses)
	or		
	0.000006	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Fluoranthene**
0.000006 mg/l

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	1.33E+03	m ²	Median of fill areas in Zone 1 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill areas in Zone 1
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 1 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	4.44E+00	m	

Calculated Parameters

Dilution Factor	DF	3.46E+00		
Level 2 Remedial Target		2.08E-05 or 2.19E-02	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant	Cr	Fluoranthene		from Level 1
Target Concentration	Cr	0.000006	mg/l	from Level 1
Dilution Factor	DF	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	1.99E+03	days Howard, 1991
Calculated decay rate	λ	3.48E-04	days ⁻¹ calculated
Width of plume in aquifer at source	Sz	5.00E+01	m from Level 2
Plume thickness in aquifer at source	Sy	4.44E+00	m from Level 2
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³ Site measurement
Effective porosity of aquifer	n	2.30E-01	fraction Literature value
Hydraulic gradient	i	4.78E-02	fraction from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d from Level 2
Distance to compliance point	x	2.50E+01	m Median distance within Zone 1
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.73E+01	l/kg see options
Longitudinal dispersivity	ax	2.500	m see options
Transverse dispersivity	az	0.250	m see options
Vertical dispersivity	ay	0.025	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	2.50E+02 fraction
Decay rate used	λ	1.39E-06 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.78E-02 fraction
Rate of contaminant flow due to retardation	u	4.74E-04 m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	9.30E-01 fraction
Attenuation factor (C ₀ /C ₁₀)	AF	1.08E+00 fraction

Remedial Targets

Level 3 Remedial Target	2.23E-05	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	2.36E-02	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	9.30E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

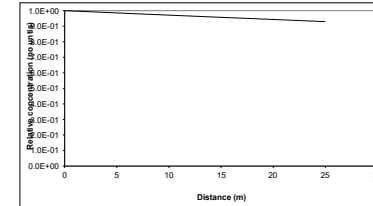
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	9.00E+00	2.50E-01	1.86E-01	m
Vertical dispersivity	ay	9.00E+00	2.50E-02	1.86E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	9.96E-01
2.5	9.93E-01
3.8	9.89E-01
5.0	9.86E-01
6.3	9.82E-01
7.5	9.78E-01
8.8	9.75E-01
10.0	9.71E-01
11.3	9.68E-01
12.5	9.64E-01
13.8	9.61E-01
15.0	9.57E-01
16.3	9.54E-01
17.5	9.50E-01
18.8	9.47E-01
20.0	9.43E-01
21.3	9.40E-01
22.5	9.36E-01
23.8	9.33E-01
25.0	9.30E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	6.29E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg
Factor (partitioning between soil and water)		1.06E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

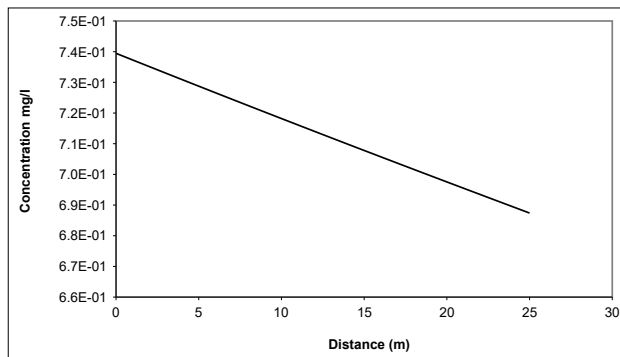
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.56E+00 mg/l	No dilution or attenuation
Level 2	C	7.39E-01 mg/l	Dilution taken into account
Level 3	C	6.87E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	7.39E-01
1.25	7.37E-01
2.50	7.34E-01
3.75	7.31E-01
5.00	7.29E-01
6.25	7.26E-01
7.50	7.23E-01
8.75	7.21E-01
10.00	7.18E-01
11.25	7.16E-01
12.50	7.13E-01
13.75	7.10E-01
15.00	7.08E-01
16.25	7.05E-01
17.50	7.03E-01
18.75	7.00E-01
20.00	6.98E-01
21.25	6.95E-01
22.50	6.92E-01
23.75	6.90E-01
25.00	6.87E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	Lead		
Target Concentration (C _T)	0.00372	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Lead
Target concentration	0.00372 mg/l

Input Parameters Standard entry

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless

Calculated
Calculated
Site measurement for made ground
N/A

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	1.00E+03	l/kg
----------------------------------	----	----------	------

Literature value

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction
Organic carbon partition coefficient	Koc		l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		pH units
Acid dissociation constant	pKa		
Fraction of organic carbon (in soil)	foc		fraction

Soil water partition coefficient used in Level Assessment	Kd	1.00E+03	l/kg	Specified value
---	----	----------	------	-----------------

Level 1 Remedial Target

Level 1 Remedial Target	3.72E+00	mg/kg	(for comparison with soil analyses)
	or		
	0.00372	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Lead
0.00372

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry

Input Parameters

Variable

Value

Unit

Source of parameter value

Infiltration
Area of contaminant source

Inf
A

1.40E-03
1.33E+03

m/d
m²

Estimated based on 60% infiltration
Median area of fill in zone 1

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.50E+01
1.50E+02
5.70E-01
3.40E-02
5.00E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Median of fill areas in Zone 1
Literature value for Chester Pebble Beds
Literature value
Site measurement
Median of fill areas in Zone 1

Not used in calculation

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Calculate
4.44E+00

m
m

Calculated Parameters

Dilution Factor

DF

3.46E+00

Level 2 Remedial Target

1.29E-02

mg/l

or

1.29E+01

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Lead		from Level 1
Target Concentration	C _r	0.00372	mg/l	from Level 1
Dilution Factor	DF	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.44E+00	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.32E-01	fraction
Hydraulic gradient	i	4.78E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	1.00E+03	l/kg
Longitudinal dispersivity	ax	2.500	m
Transverse dispersivity	az	0.250	m
Vertical dispersivity	ay	0.025	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.18E-01	m/d
Retardation factor	R _f	9.14E+03	fraction
Decay rate used	λ	8.43E-105	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.78E-02	fraction
Rate of contaminant flow due to retardation	u	1.29E-05	m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.29E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
User specified value for partition coefficient

Soil water partition coefficient	K _d	1.00E+03	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	f _{oc}		fraction
Organic carbon partition coefficient	K _{oc}		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	K _{ow}		l/kg
Sorption coefficient for ionised species	K _{ow}		l/kg
pH value	pH		
Acid dissociation constant	pK _a		
Fraction of organic carbon in aquifer	f _{oc}		fraction
Soil water partition coefficient	K _d	1.00E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

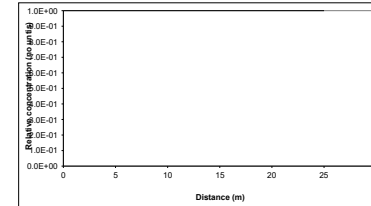
Longitudinal dispersivity	ax	2.50E+00	2.50E+00	2.50E+00	m
Transverse dispersivity	az	0.00E+00	2.50E-01	1.88E-01	m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.88E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	
From calculation sheet	
Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	1.00E+00
2.5	1.00E+00
3.8	1.00E+00
5.0	1.00E+00
6.3	1.00E+00
7.5	1.00E+00
8.8	1.00E+00
10.0	1.00E+00
11.3	1.00E+00
12.5	1.00E+00
13.8	1.00E+00
15.0	1.00E+00
16.3	1.00E+00
17.5	1.00E+00
18.8	1.00E+00
20.0	1.00E+00
21.3	1.00E+00
22.5	1.00E+00
23.8	1.00E+00
25.0	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.00E+03	l/kg
Factor (partitioning between soil and water)		1.00E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

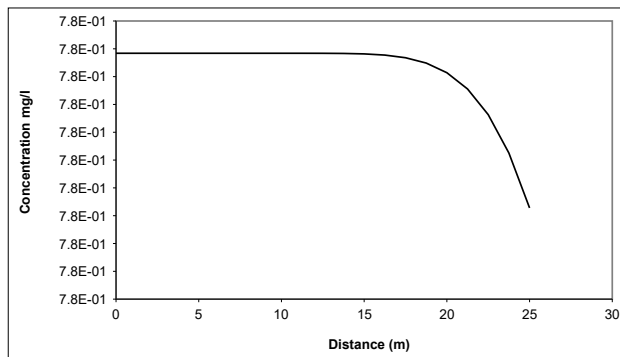
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.70E+00 mg/l	No dilution or attenuation
Level 2	C	7.80E-01 mg/l	Dilution taken into account
Level 3	C	7.80E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	7.80E-01
1.25	7.80E-01
2.50	7.80E-01
3.75	7.80E-01
5.00	7.80E-01
6.25	7.80E-01
7.50	7.80E-01
8.75	7.80E-01
10.00	7.80E-01
11.25	7.80E-01
12.50	7.80E-01
13.75	7.80E-01
15.00	7.80E-01
16.25	7.80E-01
17.50	7.80E-01
18.75	7.80E-01
20.00	7.80E-01
21.25	7.80E-01
22.50	7.80E-01
23.75	7.80E-01
25.00	7.80E-01



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	Nickel		
Target Concentration (C _T)	0.0153	mg/l	Origin of C _T : BGS background concentration, 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Nickel
Target concentration	0.0153 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80	g/cm ³	Site measurement for made ground	
Henry's Law constant	0.00	dimensionless	N/A	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	5.00E+02	l/kg	Literature value
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Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 5.00E+02 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	7.65E+00	mg/kg	(for comparison with soil analyses)
	or		
	0.0153	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T

Nickel
0.0153 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	1.33E+03	m ²	Median area of fill in Zone 1 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	2.50E+01	m	Median of fill in Zone 1
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill in Zone 1 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	4.44E+00	m	

Calculated Parameters

Dilution Factor	DF	3.46E+00
Level 2 Remedial Target		5.29E-02 mg/l or 2.65E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Nickel		from Level 1
Target Concentration	C _r	0.0153	mg/l	from Level 1
Dilution Factor	DF	3.46E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks

Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.44E+00	m
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.78E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	Kd	5.00E+02	l/kg
Longitudinal dispersivity	ax	2.500	m
Transverse dispersivity	az	0.250	m
Vertical dispersivity	ay	0.025	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	4.57E+03
Decay rate used	λ	1.69E-104 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.78E-02
Rate of contaminant flow due to retardation	u	2.60E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00

Remedial Targets

Level 3 Remedial Target	5.29E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 5.00E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc fraction

Organic carbon partition coefficient Koc l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc fraction

Soil water partition coefficient Kd 5.00E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

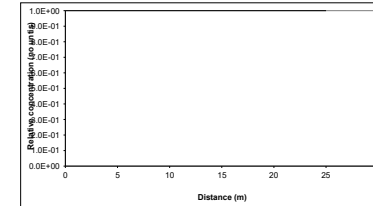
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	2.50E+00	0.00E+00 m
Transverse dispersivity	az	0.00E+00	2.50E-01	1.88E-01 m
Vertical dispersivity	ay	0.00E+00	2.50E-02	1.88E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
1.3	1.00E+00
2.5	1.00E+00
3.8	1.00E+00
5.0	1.00E+00
6.3	1.00E+00
7.5	1.00E+00
8.8	1.00E+00
10.0	1.00E+00
11.3	1.00E+00
12.5	1.00E+00
13.8	1.00E+00
15.0	1.00E+00
16.3	1.00E+00
17.5	1.00E+00
18.8	1.00E+00
20.0	1.00E+00
21.3	1.00E+00
22.5	1.00E+00
23.8	1.00E+00
25.0	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source. Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	5.00E+02	l/kg
Factor (partitioning between soil and water)		5.00E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

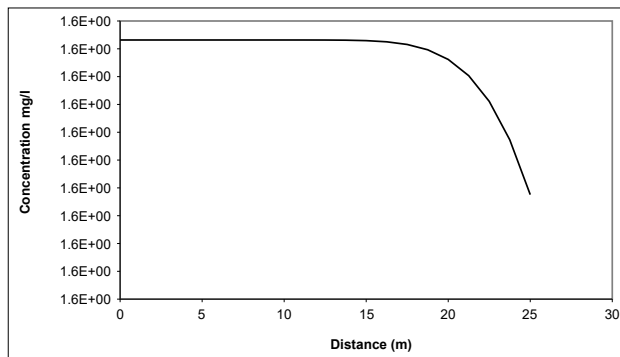
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.40E+00 mg/l	No dilution or attenuation
Level 2	C	1.56E+00 mg/l	Dilution taken into account
Level 3	C	1.56E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.56E+00
1.25	1.56E+00
2.50	1.56E+00
3.75	1.56E+00
5.00	1.56E+00
6.25	1.56E+00
7.50	1.56E+00
8.75	1.56E+00
10.00	1.56E+00
11.25	1.56E+00
12.50	1.56E+00
13.75	1.56E+00
15.00	1.56E+00
16.25	1.56E+00
17.50	1.56E+00
18.75	1.56E+00
20.00	1.56E+00
21.25	1.56E+00
22.50	1.56E+00
23.75	1.56E+00
25.00	1.56E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 1		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	Zinc		
Target Concentration (C _T)	0.1115	mg/l	Origin of C _T : BGS Baseline quality 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Zinc
Target concentration	0.1115 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80	g/cm ³	Site measurement for made ground	
Henry's Law constant	0.00	dimensionless	N/A	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	5.01E+02	l/kg	Literature value
----------------------------------	----	----------	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 5.01E+02 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	5.59E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.1115	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Zinc
0.1115

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry

Input Parameters

Variable

Value

Unit

Source of parameter value

Infiltration
Area of contaminant source

Inf
A

1.44E-03
1.33E+03

m/d
m²

Estimated based on 60% infiltration
Calculated median area of fill in Zone 1

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.50E+01
1.50E+02
5.70E-01
3.40E-02
5.00E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Calculated median length of fill in Zone 1
Literature value for Chester Pebble Beds
Literature value
Site measurement
Calculated median width of fill in Zone 1

Not used in calculation

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Calculate
4.49E+00

m
m

Calculated Parameters

Dilution Factor

DF

3.42E+00

Level 2 Remedial Target

3.81E-01

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

or

1.91E+02

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Zinc		from Level 1
Target Concentration	C _r	0.1115	mg/l	from Level 1
Dilution Factor	DF	3.42E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks

Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	4.49E+00	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	2.50E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	Kd	5.01E+02	l/kg
Longitudinal dispersivity	ax	1.863	m
Transverse dispersivity	az	0.186	m
Vertical dispersivity	ay	0.019	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01
Retardation factor	Rf	4.62E+03
Decay rate used	λ	1.67E-104
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	2.58E-05
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00

Remedial Targets

Level 3 Remedial Target	3.81E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	25	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	1.00E+00	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 5.01E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc fraction

Organic carbon partition coefficient Koc l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc fraction

Soil water partition coefficient Kd 5.01E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

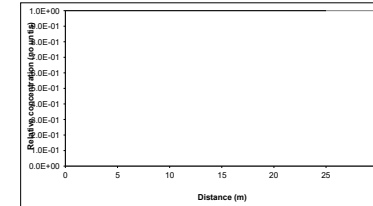
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	1.86E+00	1.86E+00 m
Transverse dispersivity	az	0.00E+00	1.86E-01 m
Vertical dispersivity	ay	0.00E+00	1.86E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
1.3	1.00E+00
2.5	1.00E+00
3.8	1.00E+00
5.0	1.00E+00
6.3	1.00E+00
7.5	1.00E+00
8.8	1.00E+00
10.0	1.00E+00
11.3	1.00E+00
12.5	1.00E+00
13.8	1.00E+00
15.0	1.00E+00
16.3	1.00E+00
17.5	1.00E+00
18.8	1.00E+00
20.0	1.00E+00
21.3	1.00E+00
22.5	1.00E+00
23.8	1.00E+00
25.0	1.00E+00

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	5.01E+02	l/kg
Factor (partitioning between soil and water)		5.01E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

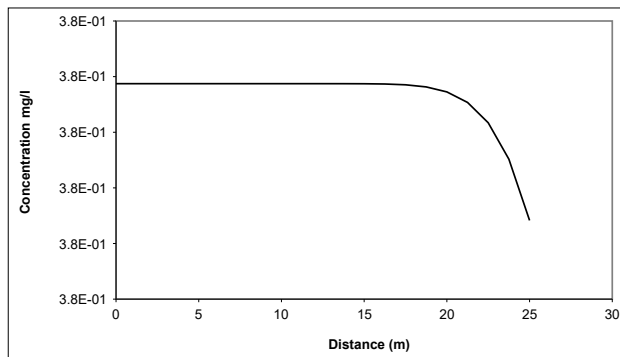
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.29E+00 mg/l	No dilution or attenuation
Level 2	C	3.77E-01 mg/l	Dilution taken into account
Level 3	C	3.77E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.77E-01
1.25	3.77E-01
2.50	3.77E-01
3.75	3.77E-01
5.00	3.77E-01
6.25	3.77E-01
7.50	3.77E-01
8.75	3.77E-01
10.00	3.77E-01
11.25	3.77E-01
12.50	3.77E-01
13.75	3.77E-01
15.00	3.77E-01
16.25	3.77E-01
17.50	3.77E-01
18.75	3.77E-01
20.00	3.77E-01
21.25	3.77E-01
22.50	3.77E-01
23.75	3.77E-01
25.00	3.77E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	TPH - Aliphatic C8-C10		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C8-C10
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.90E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	8.20E+01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	3.20E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.86E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	5.59E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **TPH - Aliphatic C8-C10** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Median of fill in zone 2 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill in zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value for Chester Pebble Beds
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill in zone 2 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00	
Level 2 Remedial Target		1.02E+00 or 1.90E+03	mg/l mg/kg
For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.			
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water			

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C8-C10		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	1.13E+01	m
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	9.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	4.80E+01	l/kg
Longitudinal dispersivity	ax	9.000	m
Transverse dispersivity	az	0.900	m
Vertical dispersivity	ay	0.090	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	R _f	4.39E+02
Decay rate used	λ	1.75E-103 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	2.71E-04 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.46E-01
Attenuation factor (C ₀ /C _{el})	AF	1.06E+00

Remedial Targets

Level 3 Remedial Target	1.08E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	2.01E+03	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
	90	m	
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.46E-01	fraction
			Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 3.20E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow} l/kgSorption coefficient for ionised species K_{ow} l/kg

pH value pH

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} 4.80E+01 l/kgSoil water partition coefficient K_d 4.80E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

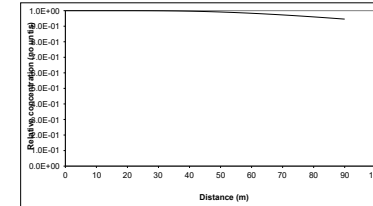
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	4.12E+00	m
Transverse dispersivity	az	9.00E+00	4.18E-01	m
Vertical dispersivity	ay	9.00E+00	4.18E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	(No units)
4.5	1.0E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	9.99E-01
36.0	9.98E-01
40.5	9.97E-01
45.0	9.94E-01
49.5	9.92E-01
54.0	9.88E-01
58.5	9.85E-01
63.0	9.80E-01
67.5	9.75E-01
72.0	9.70E-01
76.5	9.65E-01
81.0	9.59E-01
85.5	9.52E-01
90.0	9.46E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.90E+00	g/cm ³
Henry's Law constant	H	8.20E+01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.86E+03	l/kg
Factor (partitioning between soil and water)		1.86E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

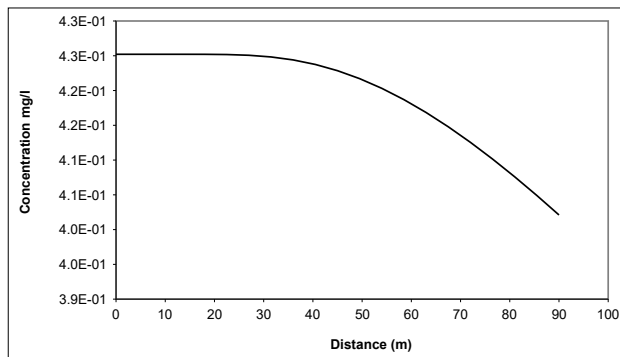
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.45E+00	mg/l	No dilution or attenuation
Level 2	C	4.25E-01	mg/l	Dilution taken into account
Level 3	C	4.02E-01	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	4.25E-01
4.50	4.25E-01
9.00	4.25E-01
13.50	4.25E-01
18.00	4.25E-01
22.50	4.25E-01
27.00	4.25E-01
31.50	4.25E-01
36.00	4.24E-01
40.50	4.24E-01
45.00	4.23E-01
49.50	4.22E-01
54.00	4.20E-01
58.50	4.19E-01
63.00	4.17E-01
67.50	4.15E-01
72.00	4.13E-01
76.50	4.10E-01
81.00	4.08E-01
85.50	4.05E-01
90.00	4.02E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	TPH - Aliphatic C10-C12		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C10-C12
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.30E+02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	2.50E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.45E+04	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	4.35E+03	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **TPH - Aliphatic C10-C12** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median of fill areas in Zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas in Zone 2
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value for Chester Pebble Beds
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00		
Level 2 Remedial Target		1.02E+00 or 1.48E+04	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C10-C12		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days	No degradation assumed
Calculated decay rate	λ	7.70E-101	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.13E+01	m	from Level 2
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	n	2.30E-01	fraction	Literature value
Hydraulic gradient	i	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d	from Level 2
Distance to compliance point	x	9.00E+01	m	Median distance in Zone 2
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+99	days	time variant options only
Parameters values determined from options				
Partition coefficient	Kd	3.75E+02	l/kg	see options
Longitudinal dispersivity	ax	4.183	m	see options
Transverse dispersivity	az	0.418	m	see options
Vertical dispersivity	ay	0.042	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	R _f	3.42E+03
Decay rate used	λ	2.25E-104 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	3.48E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.96E-01
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00

Remedial Targets

Level 3 Remedial Target		1.03E+00	mg/l	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.
Ogata Banks		or		
Distance to compliance point		90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.96E-01	fraction	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc}Organic carbon partition coefficient K_{oc}

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel}Sorption coefficient for ionised species K_{oc,i}

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc}Soil water partition coefficient K_d

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

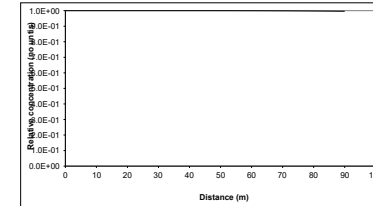
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	9.00E+00	9.00E+00 4.18E+00 m
Transverse dispersivity	az	9.00E+00	9.00E+01 4.18E-01 m
Vertical dispersivity	ay	9.00E+00	9.00E+02 4.18E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.00E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	1.00E+00
36.0	1.00E+00
40.5	1.00E+00
45.0	1.00E+00
49.5	1.00E+00
54.0	1.00E+00
58.5	1.00E+00
63.0	9.99E-01
67.5	9.98E-01
72.0	9.96E-01
76.5	9.98E-01
81.0	9.98E-01
85.5	9.97E-01
90.0	9.96E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.30E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.45E+04	l/kg
Factor (partitioning between soil and water)		1.45E+04	dimensionless

Level 2 Parameters

Dilution Factor DF

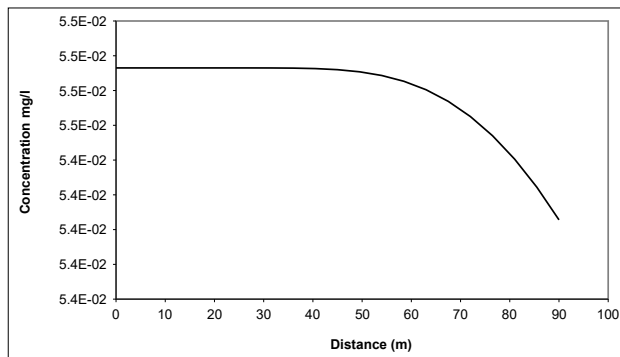
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.86E-01	mg/l	No dilution or attenuation
Level 2	C	5.46E-02	mg/l	Dilution taken into account
Level 3	C	5.44E-02	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	5.46E-02
4.50	5.46E-02
9.00	5.46E-02
13.50	5.46E-02
18.00	5.46E-02
22.50	5.46E-02
27.00	5.46E-02
31.50	5.46E-02
36.00	5.46E-02
40.50	5.46E-02
45.00	5.46E-02
49.50	5.46E-02
54.00	5.46E-02
58.50	5.46E-02
63.00	5.46E-02
67.50	5.45E-02
72.00	5.45E-02
76.50	5.45E-02
81.00	5.45E-02
85.50	5.44E-02
90.00	5.44E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	TPH - Aliphatic C12-C16		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aliphatic C12-C16
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	5.40E+02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	5.00E+06	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	2.90E+05	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	8.70E+04	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aliphatic C12-C16** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimate based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Median of fill areas in Zone 2 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas in Zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value for Chester Pebble Beds
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 2 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00		
Level 2 Remedial Target		1.02E+00 or 2.97E+05	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		TPH - Aliphatic C12-C16		from Level 1
Target Concentration	C _r	0.3	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days	No degradation assumed
Calculated decay rate	λ	7.70E-101	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.13E+01	m	from Level 2
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	n	2.30E-01	fraction	Literature value
Hydraulic gradient	i	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d	from Level 2
Distance to compliance point	x	9.00E+01	m	Median distance in Zone 2
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+99	days	time variant options only
Parameters values determined from options				
Partition coefficient	Kd	7.50E+03	l/kg	see options
Longitudinal dispersivity	ax	9.000	m	see options
Transverse dispersivity	az	0.900	m	see options
Vertical dispersivity	ay	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	R _f	6.85E+04
Decay rate used	λ	1.12E-105 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	1.74E-06 m/d
Ratio of Compliance Point to Source Concentration	C _{rel} /C ₀	9.46E-01
Attenuation factor (C ₀ /C _{rel})	AF	1.06E+00

Remedial Targets

Level 3 Remedial Target		1.08E+00	mg/l	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.
Ogata Banks		or		
Distance to compliance point		3.14E+05	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
		90	m	
Ratio of Compliance Point to Source Concentration	C _{rel} /C ₀	9.46E-01	fraction	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 5.00E+06 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow} l/kgSorption coefficient for ionised species K_{ow} l/kg

pH value pH

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} 7.50E+03 l/kgSoil water partition coefficient K_d 7.50E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

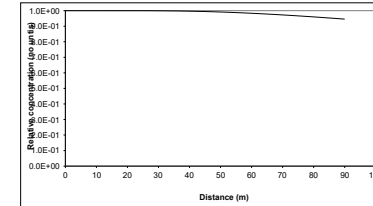
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	9.00E+00	4.12E+00 m
Transverse dispersivity	az	9.00E+00	9.00E-01	4.18E-01 m
Vertical dispersivity	ay	9.00E+00	9.00E-02	4.18E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	9.99E-01
36.0	9.98E-01
40.5	9.97E-01
45.0	9.94E-01
49.5	9.92E-01
54.0	9.88E-01
58.5	9.85E-01
63.0	9.80E-01
67.5	9.75E-01
72.0	9.70E-01
76.5	9.65E-01
81.0	9.59E-01
85.5	9.52E-01
90.0	9.46E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	5.40E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	2.90E+05	l/kg
Factor (partitioning between soil and water)		2.90E+05	dimensionless

Level 2 Parameters

Dilution Factor DF

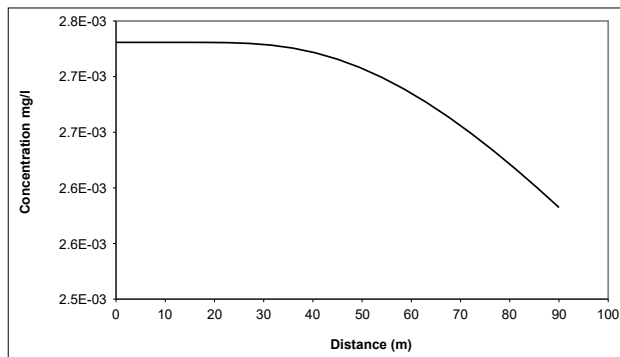
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	9.31E-03	mg/l	No dilution or attenuation
Level 2	C	2.73E-03	mg/l	Dilution taken into account
Level 3	C	2.58E-03	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.73E-03
4.50	2.73E-03
9.00	2.73E-03
13.50	2.73E-03
18.00	2.73E-03
22.50	2.73E-03
27.00	2.73E-03
31.50	2.73E-03
36.00	2.73E-03
40.50	2.72E-03
45.00	2.72E-03
49.50	2.71E-03
54.00	2.70E-03
58.50	2.69E-03
63.00	2.68E-03
67.50	2.66E-03
72.00	2.65E-03
76.50	2.63E-03
81.00	2.62E-03
85.50	2.60E-03
90.00	2.58E-03



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	Anthracene		
Target Concentration (C _T)	1.00E-04	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Anthracene
Target concentration	0.0001 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value
Water filled soil porosity θ_w	3.12E-01	fraction	Calculated
Air filled soil porosity θ_a	1.52E-01	fraction	Calculated
Bulk density of soil zone material ρ	1.80E+00	g/cm ³	Site measurement for made ground
Henry's Law constant H	1.81E-04	dimensionless	Literature value

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg	Literature value
----------------------------------	----	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground
Organic carbon partition coefficient	Koc	5.62E+03	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 3.26E+02 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	3.26E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.0001	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Anthracene
0.0001

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry

Input Parameters

Variable

Value

Unit

Source of parameter value

Infiltration
Area of contaminant source

Inf
A

1.40E-03
3.02E+03

m/d
m²

Estimated based on 60% infiltration
Median of fill in zone 2

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

6.30E+01
1.50E+02
5.70E-01
3.40E-02
5.00E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Median of fill in zone 2
Literature value for Chester Pebble Beds
Literature value
Site measurement
Median of fill in zone 2

Not used in calculation

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Calculate
1.12E+01

m
m

Calculated Parameters

Dilution Factor

DF

3.45E+00

Level 2 Remedial Target

3.45E-04
or
1.13E-01

mg/l
mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

Cc

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Anthraxene		from Level 1
Target Concentration	Cr	0.0001	mg/l	from Level 1
Dilution Factor	DF	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	t _{1/2}	4.60E+02	days Howard, 1991
Calculated decay rate	λ	1.51E-03	days ⁻¹ calculated
Width of plume in aquifer at source	Sz	5.00E+01	m from Level 2
Plume thickness in aquifer at source	Sy	1.12E+01	m from Level 2
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³ Site measurement
Effective porosity of aquifer	n	2.30E-01	fraction Literature value
Hydraulic gradient	i	4.79E-02	fraction from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d from Level 2
Distance to compliance point	x	9.00E+01	m Median of Zone 2
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.73E+01	l/kg see options
Longitudinal dispersivity	ax	9.000	m see options
Transverse dispersivity	az	0.900	m see options
Vertical dispersivity	ay	0.090	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01	m/d
Retardation factor	Rf	2.50E+02	fraction
Decay rate used	λ	6.02E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.79E-02	fraction
Rate of contaminant flow due to retardation	u	4.74E-04	m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	3.36E-01	fraction
Attenuation factor (C ₀ /C ₁₀)	AF	2.98E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.03E-03	mg/l	For comparison with measured pore water concentration.
Ogata Banks	3.36E-01	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	3.36E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)		
Soil water partition coefficient	Kd	l/kg
Entry for non-polar organic chemicals (option)		
Fraction of organic carbon in aquifer	foc	1.50E-03 fraction
Organic carbon partition coefficient	Koc	1.82E+04 l/kg
Entry for ionic organic chemicals (option)		
Sorption coefficient for related species	K _{oc,0}	l/kg
Sorption coefficient for ionised species	K _{oc,i}	l/kg
pH value	pH	
Acid dissociation constant	pKa	
Fraction of organic carbon in aquifer	foc	fraction
Soil water partition coefficient	Kd	2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

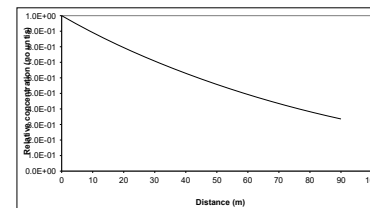
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	9.00E+00	9.00E-01	4.18E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	4.18E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration
From calculation sheet	
Distance	(No units)
0	1.0E+00
4.5	9.50E-01
9.0	9.02E-01
13.5	8.56E-01
18.0	8.13E-01
22.5	7.72E-01
27.0	7.33E-01
31.5	6.95E-01
36.0	6.60E-01
40.5	6.25E-01
45.0	5.92E-01
49.5	5.61E-01
54.0	5.31E-01
58.5	5.02E-01
63.0	4.75E-01
67.5	4.49E-01
72.0	4.24E-01
76.5	4.00E-01
81.0	3.77E-01
85.5	3.56E-01
90.0	3.36E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.81E-04	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.26E+02	l/kg
Factor (partitioning between soil and water)		3.26E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

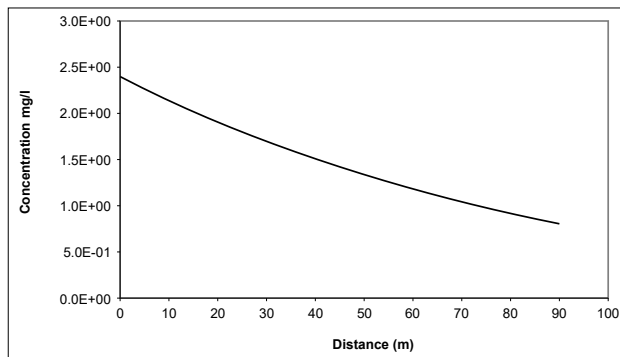
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	8.27E+00 mg/l	No dilution or attenuation
Level 2	C	2.40E+00 mg/l	Dilution taken into account
Level 3	C	8.05E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.40E+00
4.50	2.28E+00
9.00	2.16E+00
13.50	2.05E+00
18.00	1.95E+00
22.50	1.85E+00
27.00	1.76E+00
31.50	1.67E+00
36.00	1.58E+00
40.50	1.50E+00
45.00	1.42E+00
49.50	1.35E+00
54.00	1.27E+00
58.50	1.20E+00
63.00	1.14E+00
67.50	1.08E+00
72.00	1.02E+00
76.50	9.59E-01
81.00	9.05E-01
85.50	8.53E-01
90.00	8.05E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C8-C10		
Target Concentration (C _T)	3.00E-01	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C8-C10
Target concentration	0.3 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	4.90E-01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.60E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	9.28E+01	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	2.79E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C8-C10** from Level 1
0.3 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median of fill areas in Zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas in Zone 2
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00		
Level 2 Remedial Target		1.02E+00 or 9.51E+01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C8-C10		from Level 1
Target Concentration	0.3	mg/l	from Level 1
Dilution Factor	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.94E+02	days	Howard, 1991
Calculated decay rate	2.36E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.13E+01	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.40E+00	l/kg	see options
Longitudinal dispersivity	9.000	m	see options
Transverse dispersivity	0.900	m	see options
Vertical dispersivity	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	2.29E+01	fraction
Decay rate used	1.03E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.81E-02	fraction
Rate of contaminant flow due to retardation	5.20E-03	m/d
Ratio of Compliance Point to Source Concentration	2.02E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	4.94E+00	fraction

Remedial Targets

Level 3 Remedial Target	5.05E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	2.02E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 1.80E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 2.40E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

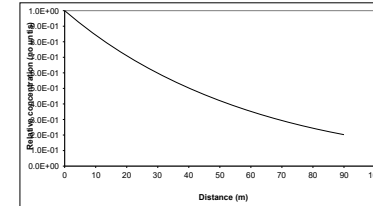
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	4.18E+00	m
Transverse dispersivity	az	9.00E+00	9.00E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
4.5	9.26E-01
9.0	8.57E-01
13.5	7.94E-01
18.0	7.35E-01
22.5	6.80E-01
27.0	6.29E-01
31.5	5.82E-01
36.0	5.39E-01
40.5	4.98E-01
45.0	4.60E-01
49.5	4.25E-01
54.0	3.92E-01
58.5	3.61E-01
63.0	3.33E-01
67.5	3.07E-01
72.0	2.83E-01
76.5	2.60E-01
81.0	2.39E-01
85.5	2.20E-01
90.0	2.02E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	4.90E-01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.28E+01	l/kg
Factor (partitioning between soil and water)		9.30E+01	dimensionless

Level 2 Parameters

Dilution Factor DF

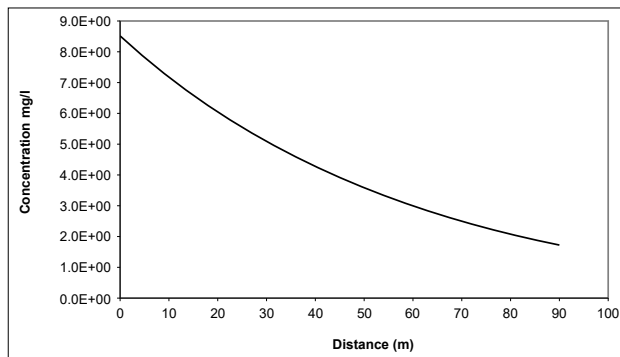
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.90E+01 mg/l	No dilution or attenuation
Level 2	C	8.52E+00 mg/l	Dilution taken into account
Level 3	C	1.72E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	8.52E+00
4.50	7.88E+00
9.00	7.30E+00
13.50	6.76E+00
18.00	6.26E+00
22.50	5.79E+00
27.00	5.36E+00
31.50	4.96E+00
36.00	4.59E+00
40.50	4.24E+00
45.00	3.92E+00
49.50	3.62E+00
54.00	3.34E+00
58.50	3.08E+00
63.00	2.84E+00
67.50	2.61E+00
72.00	2.41E+00
76.50	2.22E+00
81.00	2.04E+00
85.50	1.87E+00
90.00	1.72E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	TPH - Aromatic C10-C12		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C10-C12
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.40E-01	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	2.50E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.45E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	1.31E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C10-C12** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median of fill within Zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill within Zone 2
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill within Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00		
Level 2 Remedial Target		3.07E-01 or 4.45E+01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C10-C12		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.58E+02	days	Howard, 1991
Calculated decay rate	2.69E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.13E+01	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median distance within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	3.75E+00	l/kg	see options
Longitudinal dispersivity	9.000	m	see options
Transverse dispersivity	0.900	m	see options
Vertical dispersivity	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	3.52E+01	fraction
Decay rate used	7.62E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.81E-02	fraction
Rate of contaminant flow due to retardation	3.38E-03	m/d
Ratio of Compliance Point to Source Concentration	1.68E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	5.96E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.83E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	1.68E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 2.50E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 3.75E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

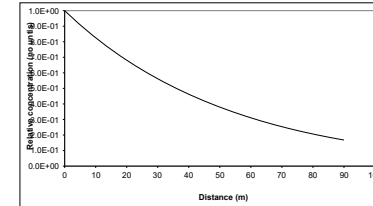
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	4.18E+00	m
Transverse dispersivity	az	9.00E+00	9.00E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	9.17E-01
9.0	8.41E-01
13.5	7.72E-01
18.0	7.08E-01
22.5	6.49E-01
27.0	5.95E-01
31.5	5.46E-01
36.0	5.00E-01
40.5	4.58E-01
45.0	4.19E-01
49.5	3.83E-01
54.0	3.50E-01
58.5	3.20E-01
63.0	2.92E-01
67.5	2.67E-01
72.0	2.43E-01
76.5	2.22E-01
81.0	2.02E-01
85.5	1.84E-01
90.0	1.68E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.40E-01	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.45E+02	l/kg
Factor (partitioning between soil and water)		1.45E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

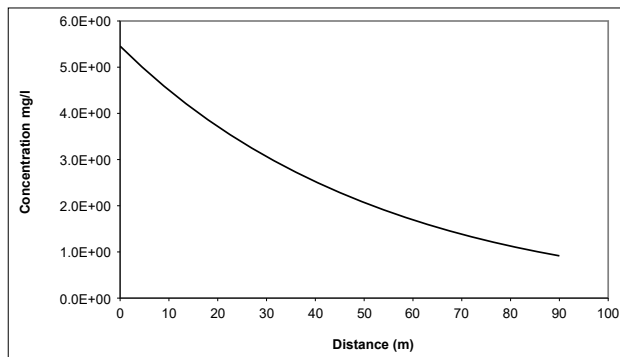
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.86E+01 mg/l	No dilution or attenuation
Level 2	C	5.46E+00 mg/l	Dilution taken into account
Level 3	C	9.16E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	5.46E+00
4.50	5.00E+00
9.00	4.59E+00
13.50	4.21E+00
18.00	3.86E+00
22.50	3.54E+00
27.00	3.25E+00
31.50	2.98E+00
36.00	2.73E+00
40.50	2.50E+00
45.00	2.29E+00
49.50	2.09E+00
54.00	1.91E+00
58.50	1.75E+00
63.00	1.59E+00
67.50	1.46E+00
72.00	1.33E+00
76.50	1.21E+00
81.00	1.10E+00
85.50	1.01E+00
90.00	9.16E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C12-C16		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C12-C16
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	5.40E-02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	5.00E+03	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	2.90E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	2.61E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C12-C16** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median of fill areas within Zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas within Zone 2
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas within Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.12E+01	m	

Calculated Parameters

Dilution Factor	DF	3.45E+00		
Level 2 Remedial Target		3.10E-01 or 9.01E+01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C12-C16		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.62E+02	days	Howard, 1991
Calculated decay rate	4.28E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.12E+01	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.79E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median distance within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	7.50E+00	l/kg	see options
Longitudinal dispersivity	9.000	m	see options
Transverse dispersivity	0.900	m	see options
Vertical dispersivity	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	6.95E+01	fraction
Decay rate used	6.16E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.79E-02	fraction
Rate of contaminant flow due to retardation	1.71E-03	m/d
Ratio of Compliance Point to Source Concentration	7.16E-02	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.40E+01	fraction

Remedial Targets

Level 3 Remedial Target	4.33E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	1.26E+03	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
	90	m	
Ratio of Compliance Point to Source Concentration	C ₁₀₀ /C ₀	7.16E-02	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 5.00E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 7.50E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

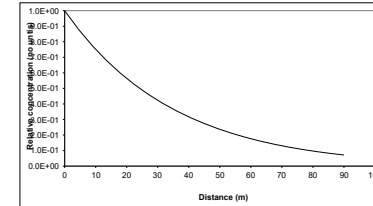
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	9.00E+00	9.00E-01	4.18E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	4.18E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
	(No units)
0	1.0E+00
4.5	8.79E-01
9.0	7.73E-01
13.5	6.79E-01
18.0	5.97E-01
22.5	5.25E-01
27.0	4.61E-01
31.5	4.05E-01
36.0	3.56E-01
40.5	3.12E-01
45.0	2.74E-01
49.5	2.40E-01
54.0	2.10E-01
58.5	1.84E-01
63.0	1.61E-01
67.5	1.41E-01
72.0	1.23E-01
76.5	1.08E-01
81.0	9.40E-02
85.5	8.21E-02
90.0	7.16E-02

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	5.40E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	2.90E+02	l/kg
Factor (partitioning between soil and water)		2.90E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

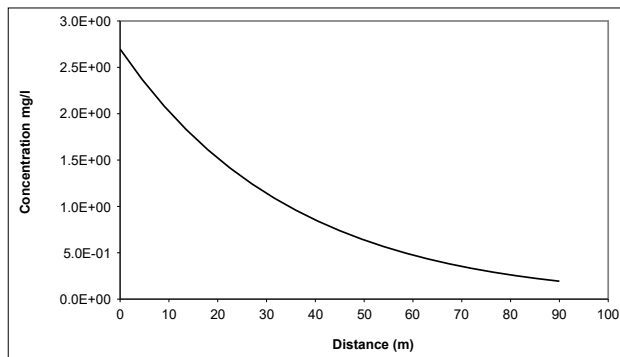
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	9.30E+00 mg/l	No dilution or attenuation
Level 2	C	2.70E+00 mg/l	Dilution taken into account
Level 3	C	1.93E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	2.70E+00
4.50	2.37E+00
9.00	2.08E+00
13.50	1.83E+00
18.00	1.61E+00
22.50	1.41E+00
27.00	1.24E+00
31.50	1.09E+00
36.00	9.59E-01
40.50	8.42E-01
45.00	7.38E-01
49.50	6.47E-01
54.00	5.67E-01
58.50	4.96E-01
63.00	4.34E-01
67.50	3.80E-01
72.00	3.32E-01
76.50	2.90E-01
81.00	2.53E-01
85.50	2.21E-01
90.00	1.93E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C16-C21		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C16-C21
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.30E-02	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.60E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	9.28E+02	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	8.35E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C16-C21** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median value for fill in Zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median value for fill in Zone 2
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median value for fill in Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.12E+01	m	

Calculated Parameters

Dilution Factor	DF	3.45E+00		
Level 2 Remedial Target		3.10E-01 or 2.88E+02	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C16-C21		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks

Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.31E+03	days	Howard, 1991
Calculated decay rate	5.29E-04	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.12E+01	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.79E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median distance in Zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.40E+01	l/kg	see options
Longitudinal dispersivity	9.000	m	see options
Transverse dispersivity	0.900	m	see options
Vertical dispersivity	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	2.20E+02	fraction
Decay rate used	2.40E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.79E-02	fraction
Rate of contaminant flow due to retardation	5.39E-04	m/d
Ratio of Compliance Point to Source Concentration	6.42E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	1.56E+00	fraction

Remedial Targets

Level 3 Remedial Target	4.83E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	6.42E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.80E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.40E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

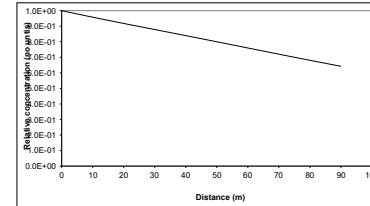
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	4.18E+01	m
Transverse dispersivity	az	9.00E+00	9.00E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	9.81E-01
9.0	9.62E-01
13.5	9.44E-01
18.0	9.26E-01
22.5	9.08E-01
27.0	8.90E-01
31.5	8.73E-01
36.0	8.55E-01
40.5	8.37E-01
45.0	8.20E-01
49.5	8.02E-01
54.0	7.84E-01
58.5	7.66E-01
63.0	7.48E-01
67.5	7.30E-01
72.0	7.12E-01
76.5	6.94E-01
81.0	6.77E-01
85.5	6.59E-01
90.0	6.42E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.28E+02	l/kg
Factor (partitioning between soil and water)		9.28E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

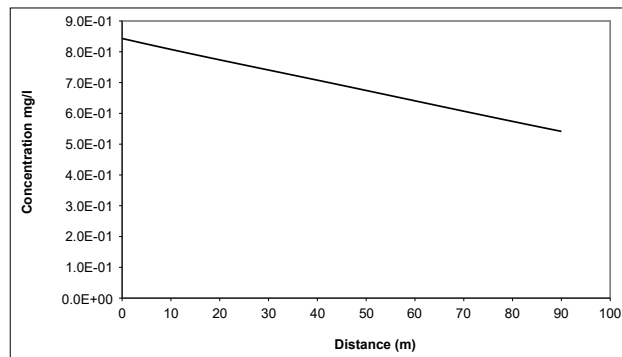
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.91E+00 mg/l	No dilution or attenuation
Level 2	C	8.43E-01 mg/l	Dilution taken into account
Level 3	C	5.42E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	8.43E-01
4.50	8.27E-01
9.00	8.11E-01
13.50	7.96E-01
18.00	7.80E-01
22.50	7.65E-01
27.00	7.51E-01
31.50	7.36E-01
36.00	7.21E-01
40.50	7.06E-01
45.00	6.91E-01
49.50	6.76E-01
54.00	6.61E-01
58.50	6.46E-01
63.00	6.31E-01
67.50	6.15E-01
72.00	6.00E-01
76.50	5.85E-01
81.00	5.71E-01
85.50	5.56E-01
90.00	5.42E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	TPH - Aromatic C21-C35		
Target Concentration (C _T)	9.00E-02	mg/l	Origin of C _T : WHO

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	TPH - Aromatic C21-C35
Target concentration	0.09 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.80E-04	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.79E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.09	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant Target concentration C_T **TPH - Aromatic C21-C35** from Level 1
0.09 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median of fill within Zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill within Zone
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill within Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.12E+01	m	

Calculated Parameters

Dilution Factor	DF	3.45E+00		
Level 2 Remedial Target		3.10E-01 or 2.34E+03	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	TPH - Aromatic C21-C35		from Level 1
Target Concentration	0.09	mg/l	from Level 1
Dilution Factor	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks

Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	1.81E+03	days	Howard, 1991
Calculated decay rate	3.82E-04	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.12E+01	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.79E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median distance within zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	9.000	m	see options
Transverse dispersivity	0.900	m	see options
Vertical dispersivity	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable		
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	1.78E+03 fraction
Decay rate used	λ	2.15E-07 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.79E-02 fraction
Rate of contaminant flow due to retardation	u	6.66E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{EO} /C _S	7.13E-01 fraction
Attenuation factor (C ₀ /C _{EO})	AF	1.40E+00 fraction

Remedial Targets

Level 3 Remedial Target	4.36E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	3.28E+03	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EO} /C _S	7.13E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

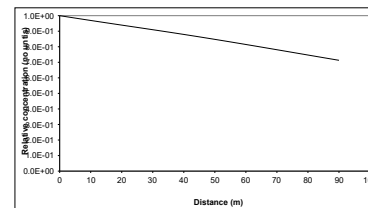
Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	
Transverse dispersivity	az	9.00E+00	9.00E-01	4.18E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	4.18E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	9.86E-01
9.0	9.72E-01
13.5	9.59E-01
18.0	9.45E-01
22.5	9.32E-01
27.0	9.19E-01
31.5	9.05E-01
36.0	8.92E-01
40.5	8.78E-01
45.0	8.64E-01
49.5	8.49E-01
54.0	8.35E-01
58.5	8.20E-01
63.0	8.05E-01
67.5	7.89E-01
72.0	7.74E-01
76.5	7.59E-01
81.0	7.43E-01
85.5	7.28E-01
90.0	7.13E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	6.80E-04	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

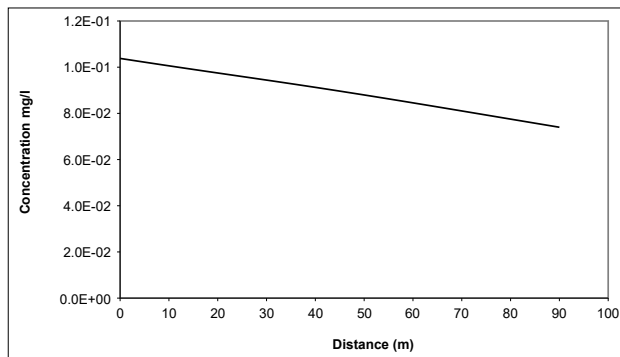
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	3.58E-01 mg/l	No dilution or attenuation
Level 2	C	1.04E-01 mg/l	Dilution taken into account
Level 3	C	7.40E-02 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.04E-01
4.50	1.02E-01
9.00	1.01E-01
13.50	9.95E-02
18.00	9.81E-02
22.50	9.67E-02
27.00	9.53E-02
31.50	9.40E-02
36.00	9.25E-02
40.50	9.11E-02
45.00	8.96E-02
49.50	8.81E-02
54.00	8.66E-02
58.50	8.51E-02
63.00	8.35E-02
67.50	8.19E-02
72.00	8.03E-02
76.50	7.88E-02
81.00	7.72E-02
85.50	7.56E-02
90.00	7.40E-02



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	Benzo(a)Pyrene		
Target Concentration (C _T)	1.00E-05	mg/l	Origin of C _T : Background concentration in Irk

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Benzo(a)Pyrene
Target concentration	0.00001 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	1.92E-05	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.30E+05	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	7.54E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.00001	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Benzo(a)Pyrene
0.00001

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	1.44E-03	m/d	Calculated assuming 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median area of fill in zone 2 Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median length of fill areas zone 2
Saturated aquifer thickness	da	1.50E+02	m	Minimum thickness of Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Geometric mean for Chester Formation
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median width of fill in zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00
Level 2 Remedial Target		3.41E-05 mg/l or 2.57E-01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzo(a)Pyrene		from Level 1
Target Concentration	Cr	0.00001	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration		
Half life for degradation of contaminant in water	t _{1/2}	1.06E+03 days	Howard 1991
Calculated decay rate	λ	6.54E-04 days ⁻¹	calculated
Width of plume in aquifer at source	Sz	5.00E+01 m	from Level 2
Plume thickness in aquifer at source	Sy	1.13E+01 m	from Level 2
Bulk density of aquifer materials	ρ	2.12E+00 g/cm ³	Site measurement
Effective porosity of aquifer	n	2.32E-01 fraction	Literature value
Hydraulic gradient	i	4.81E-02 fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01 m/d	from Level 2
Distance to compliance point	x	9.00E+01 m	Median distance within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction	z		
Distance (depth) to compliance point perpendicular to flow direction	y		
Time since pollutant entered groundwater	t	1.00E+99 days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	1.95E+02 l/kg	see options
Longitudinal dispersivity	ax	4.183 m	see options
Transverse dispersivity	az	0.418 m	see options
Vertical dispersivity	ay	0.042 m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.18E-01	m/d
Retardation factor	Rf	1.78E+03	fraction
Decay rate used	λ	3.67E-07	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02	fraction
Rate of contaminant flow due to retardation	u	6.63E-05	m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	6.12E-01	fraction
Attenuation factor (C ₀ /C ₁₀)	AF	1.63E+00	fraction

Remedial Targets

Level 3 Remedial Target	5.57E-05	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	6.12E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.30E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 1.95E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

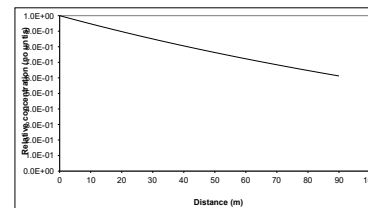
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	9.00E+01	9.00E+01 4.18E+00 m
Transverse dispersivity	az	9.00E+00	9.00E+01 4.18E-01 m
Vertical dispersivity	ay	9.00E+00	9.00E+02 4.18E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration
From calculation sheet	(No units)
Distance	Relative concentration
0	1.0E+00
4.5	9.76E-01
9.0	9.52E-01
13.5	9.30E-01
18.0	9.07E-01
22.5	8.85E-01
27.0	8.64E-01
31.5	8.43E-01
36.0	8.23E-01
40.5	8.03E-01
45.0	7.84E-01
49.5	7.65E-01
54.0	7.47E-01
58.5	7.28E-01
63.0	7.11E-01
67.5	6.93E-01
72.0	6.77E-01
76.5	6.60E-01
81.0	6.44E-01
85.5	6.28E-01
90.0	6.12E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.92E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

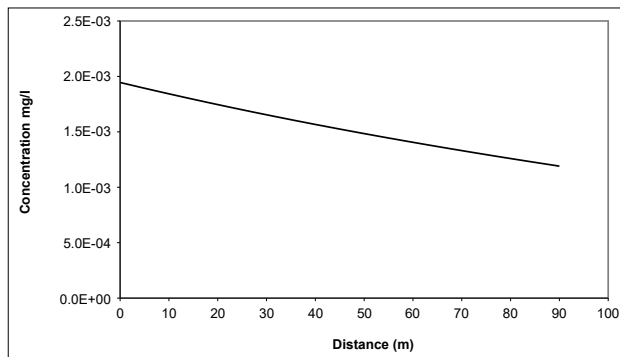
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	6.63E-03	mg/l	No dilution or attenuation
Level 2	C	1.95E-03	mg/l	Dilution taken into account
Level 3	C	1.19E-03	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.95E-03
4.50	1.90E-03
9.00	1.85E-03
13.50	1.81E-03
18.00	1.76E-03
22.50	1.72E-03
27.00	1.68E-03
31.50	1.64E-03
36.00	1.60E-03
40.50	1.56E-03
45.00	1.52E-03
49.50	1.49E-03
54.00	1.45E-03
58.50	1.42E-03
63.00	1.38E-03
67.50	1.35E-03
72.00	1.32E-03
76.50	1.28E-03
81.00	1.25E-03
85.50	1.22E-03
90.00	1.19E-03



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH		
Date:	01-Nov-22	Version:	3
Contaminant	Benzo(a)Pyrene		
Target Concentration (C _T)	1.00E-05	mg/l	Origin of C _T : Background concentration in Irk

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Benzo(a)Pyrene
Target concentration	0.00001 mg/l

Input Parameters

Standard entry

Variable	Value	Unit	Source of parameter value
Water filled soil porosity θ_w	3.12E-01	fraction	Calculated
Air filled soil porosity θ_a	1.52E-01	fraction	Calculated
Bulk density of soil zone material ρ	1.80E+00	g/cm ³	Site measurement for made ground
Henry's Law constant H	1.92E-05	dimensionless	Literature value

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd		l/kg	Literature value
-------------------------------------	--	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil) foc	5.80E-02	fraction	Site measurement for made ground
Organic carbon partition coefficient Koc	1.30E+05	l/kg	Literature value

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species $K_{oc,n}$		l/kg	
Sorption coefficient for ionised species $K_{oc,i}$		l/kg	
pH value pH		pH units	
Acid dissociation constant pKa			
Fraction of organic carbon (in soil) foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 7.54E+03 l/kg Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	7.54E-02	mg/kg	(for comparison with soil analyses)
	or		
	0.00001	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Benzo(a)Pyrene** from Level 1
0.00001 mg/l from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
<i>Standard entry</i>				
Infiltration	Inf	1.44E-03	m/d	Calculated assuming 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median area of fill in zone 2 <i>Not used in calculation</i>
<i>Entry for groundwater flow below site</i>				
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median length of fill areas zone 2
Saturated aquifer thickness	da	1.50E+02	m	Minimum thickness of Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Geometric mean for Chester Formation
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median width of fill in zone 2 <i>Not used in calculation</i>
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00		
Level 2 Remedial Target		3.41E-05 or 2.57E-01	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzo(a)Pyrene		from Level 1
Target Concentration	Cr	0.00001	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.94E+02	days	Howard 1991
Calculated decay rate	2.36E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.13E+01	m	from Level 2
Bulk density of aquifer materials	2.12E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.32E-01	fraction	Literature value
Hydraulic gradient	4.81E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median distance within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	1.95E+02	l/kg	see options
Longitudinal dispersivity	4.183	m	see options
Transverse dispersivity	0.418	m	see options
Vertical dispersivity	0.042	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.18E-01	m/d
Retardation factor	1.78E+03	fraction
Decay rate used	1.32E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.81E-02	fraction
Rate of contaminant flow due to retardation	6.63E-05	m/d
Ratio of Compliance Point to Source Concentration	1.88E-01	fraction
Attenuation factor (C ₀ /C ₁₀₀)	5.31E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.81E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	1.37E+00	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
	90	m	
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀₀	1.88E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer

Organic carbon partition coefficient

Entry for ionic organic chemicals (option)

Sorption coefficient for related species

Sorption coefficient for ionised species

pH value

Acid dissociation constant

Fraction of organic carbon in aquifer

Soil water partition coefficient

K_d

foc

K_{oc}K_{oc,ion}

pH

pKa

fraction

K_d

1.95E+02

l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

Longitudinal dispersivity

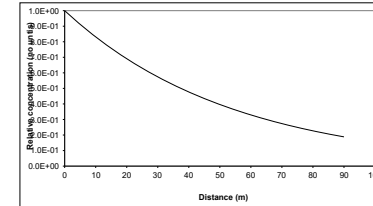
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance

Relative concentration

(No units)

0

1.0E+00

4.5

9.20E-01

9.0

8.47E-01

13.5

7.79E-01

18.0

7.17E-01

22.5

6.59E-01

27.0

6.07E-01

31.5

5.58E-01

36.0

5.14E-01

40.5

4.73E-01

45.0

4.35E-01

49.5

4.00E-01

54.0

3.68E-01

58.5

3.38E-01

63.0

3.11E-01

67.5

2.86E-01

72.0

2.63E-01

76.5

2.42E-01

81.0

2.23E-01

85.5

2.05E-01

90.0

1.88E-01

Site being assessed: Victoria North HIF Infrastructure Works

Completed by: DH

Date: #####

Version: 3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	1.92E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	7.54E+03	l/kg
Factor (partitioning between soil and water)		7.54E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

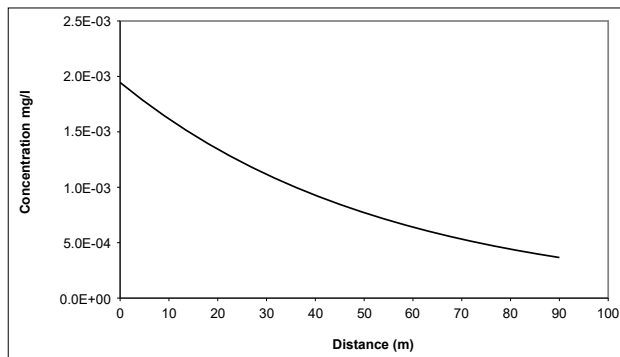
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	6.63E-03	mg/l	No dilution or attenuation
Level 2	C	1.95E-03	mg/l	Dilution taken into account
Level 3	C	3.66E-04	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.95E-03
4.50	1.79E-03
9.00	1.65E-03
13.50	1.52E-03
18.00	1.39E-03
22.50	1.28E-03
27.00	1.18E-03
31.50	1.09E-03
36.00	9.99E-04
40.50	9.19E-04
45.00	8.46E-04
49.50	7.78E-04
54.00	7.16E-04
58.50	6.58E-04
63.00	6.06E-04
67.50	5.57E-04
72.00	5.12E-04
76.50	4.71E-04
81.00	4.33E-04
85.50	3.98E-04
90.00	3.66E-04



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	Chromium		
Target Concentration (C_T)	0.0057	mg/l	Origin of C_T: BGS background concentration, 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Chromium
Target concentration	0.0057 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value
Water filled soil porosity θ_w	3.12E-01	fraction	Calculated
Air filled soil porosity θ_a	1.52E-01	fraction	Calculated
Bulk density of soil zone material ρ	1.80E+00	g/cm ³	Site measurement for made ground
Henry's Law constant H	0.00E+00	dimensionless	N/A

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	4.80E+03	l/kg	Literature value
----------------------------------	----	----------	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 4.80E+03 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	2.74E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.0057	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Chromium
0.0057

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Median area of fill in Zone 2 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median length of fill in Zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Minimum thickness of Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median width of fill in Zone 2 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00
Level 2 Remedial Target		1.94E-02 mg/l or 9.33E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Chromium		from Level 1
Target Concentration	C _r	0.0057	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	1.13E+01	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.32E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	9.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	4.80E+03	l/kg
Longitudinal dispersivity	ax	4.183	m
Transverse dispersivity	az	0.418	m
Vertical dispersivity	ay	0.042	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.18E-01 m/d
Retardation factor	R _f	4.39E+04
Decay rate used	λ	1.76E-105 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	2.70E-06 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.96E-01
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00

Remedial Targets

Level 3 Remedial Target	1.95E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.96E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d 4.80E+03 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc}Organic carbon partition coefficient K_{oc}

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow}Sorption coefficient for ionised species K_{ow}

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc}Soil water partition coefficient K_d 4.80E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

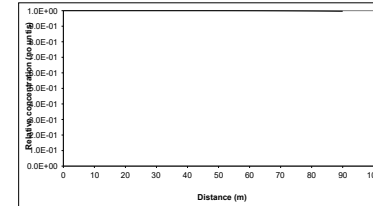
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	4.183	4.18E+00 m
Transverse dispersivity	az	0.418	4.18E-01 m
Vertical dispersivity	ay	0.042	4.18E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	1.00E+00
36.0	1.00E+00
40.5	1.00E+00
45.0	1.00E+00
49.5	1.00E+00
54.0	1.00E+00
58.5	1.00E+00
63.0	9.99E-01
67.5	9.98E-01
72.0	9.98E-01
76.5	9.98E-01
81.0	9.98E-01
85.5	9.97E-01
90.0	9.96E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	4.80E+03	l/kg
Factor (partitioning between soil and water)		4.80E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

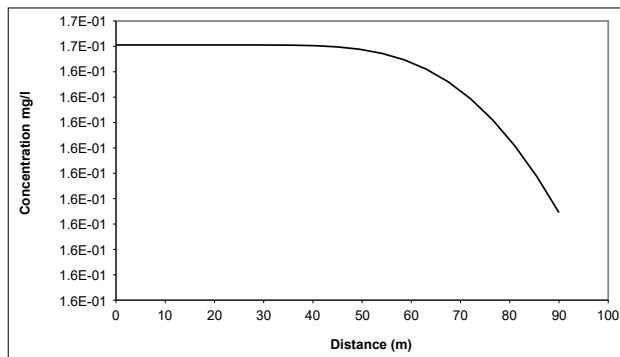
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.62E-01	mg/l	No dilution or attenuation
Level 2	C	1.65E-01	mg/l	Dilution taken into account
Level 3	C	1.64E-01	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.65E-01
4.50	1.65E-01
9.00	1.65E-01
13.50	1.65E-01
18.00	1.65E-01
22.50	1.65E-01
27.00	1.65E-01
31.50	1.65E-01
36.00	1.65E-01
40.50	1.65E-01
45.00	1.65E-01
49.50	1.65E-01
54.00	1.65E-01
58.50	1.65E-01
63.00	1.65E-01
67.50	1.65E-01
72.00	1.65E-01
76.50	1.65E-01
81.00	1.65E-01
85.50	1.64E-01
90.00	1.64E-01



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	Copper		
Target Concentration (C _T)	0.028	mg/l	Origin of C _T : BGS background concentration, 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Copper
Target concentration	0.028 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80	g/cm ³	Site measurement for made ground	
Henry's Law constant	0.00	dimensionless	N/A	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	5.01E+02	l/kg	Literature value
----------------------------------	----	----------	------	------------------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 5.01E+02 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	1.40E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.028	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T

Copper
0.028 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Median of fill areas in Zone 2 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas in Zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 2 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00
Level 2 Remedial Target		9.54E-02 mg/l or 4.79E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Copper		from Level 1
Target Concentration	C _r	0.028	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	1.13E+01	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	9.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	5.01E+02	l/kg
Longitudinal dispersivity	ax	9.000	m
Transverse dispersivity	az	0.900	m
Vertical dispersivity	ay	0.090	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	R _f	4.62E+03
Decay rate used	λ	1.67E-104 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	2.58E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.46E-01
Attenuation factor (C ₀ /C _{el})	AF	1.06E+00

Remedial Targets

Level 3 Remedial Target	1.01E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	5.06E+01	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.46E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d 5.01E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc}Organic carbon partition coefficient K_{oc}

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{ow}Sorption coefficient for ionised species K_{ow}

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc}Soil water partition coefficient K_d 5.01E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

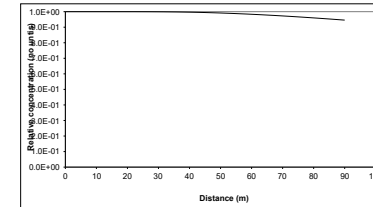
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	4.12E+00	m
Transverse dispersivity	az	9.00E+00	4.18E+01	m
Vertical dispersivity	ay	9.00E+00	4.18E+02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	9.99E-01
36.0	9.98E-01
40.5	9.97E-01
45.0	9.94E-01
49.5	9.92E-01
54.0	9.88E-01
58.5	9.85E-01
63.0	9.80E-01
67.5	9.75E-01
72.0	9.70E-01
76.5	9.65E-01
81.0	9.59E-01
85.5	9.52E-01
90.0	9.46E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	5.01E+02	l/kg
Factor (partitioning between soil and water)		5.01E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

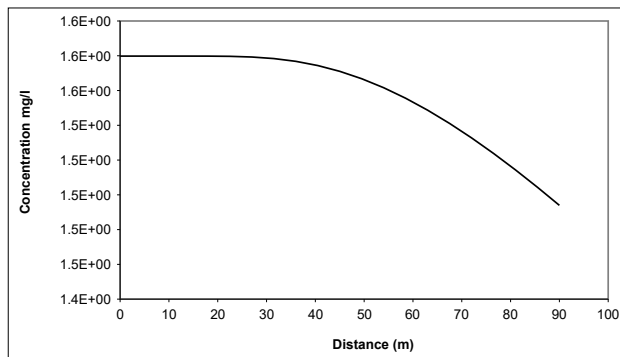
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.39E+00 mg/l	No dilution or attenuation
Level 2	C	1.58E+00 mg/l	Dilution taken into account
Level 3	C	1.49E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.58E+00
4.50	1.58E+00
9.00	1.58E+00
13.50	1.58E+00
18.00	1.58E+00
22.50	1.58E+00
27.00	1.58E+00
31.50	1.58E+00
36.00	1.58E+00
40.50	1.57E+00
45.00	1.57E+00
49.50	1.57E+00
54.00	1.56E+00
58.50	1.56E+00
63.00	1.55E+00
67.50	1.54E+00
72.00	1.53E+00
76.50	1.52E+00
81.00	1.51E+00
85.50	1.50E+00
90.00	1.49E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	Fluoranthene		
Target Concentration (C _T)	6.00E-06	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Fluoranthene
Target concentration	0.000006 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.29E-05	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.82E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.33E-03	mg/kg	(for comparison with soil analyses)
	or		
	0.000006	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Fluoranthene
0.000006

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry

Input Parameters

Variable

Value

Unit

Source of parameter value

Infiltration
Area of contaminant source

Inf
A

1.40E-03
3.02E+03

m/d
m²

Estimated based on 60% infiltration
Median of fill areas in Zone 2

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

6.30E+01
1.50E+02
5.70E-01
3.40E-02
5.00E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Median of fill areas in Zone 2
Literature value for Chester Pebble Beds
Literature value
Site measurement
Median of fill areas in Zone 2

Not used in calculation

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Calculate
1.12E+01

m
m

Calculated Parameters

Dilution Factor

DF

3.45E+00

Level 2 Remedial Target

2.07E-05
or
2.19E-02

mg/l
mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

Cc

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 01-Nov-22
Version: 3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant	Cr	Fluoranthene		from Level 1
Target Concentration		0.000006	mg/l	from Level 1
Dilution Factor	DF	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	2.90E+02	days	Howard, 1991
Calculated decay rate	2.39E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	1.12E+01	m	from Level 2
Bulk density of aquifer materials	2.10E+00	g/cm ³	Site measurement
Effective porosity of aquifer	2.30E-01	fraction	Literature value
Hydraulic gradient	4.79E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	5.70E-01	m/d	from Level 2
Distance to compliance point	9.00E+01	m	Median distance within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	2.73E+01	l/kg	see options
Longitudinal dispersivity	9.000	m	see options
Transverse dispersivity	0.900	m	see options
Vertical dispersivity	0.090	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	1.19E-01	m/d
Retardation factor	2.50E+02	fraction
Decay rate used	9.55E-06	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	4.79E-02	fraction
Rate of contaminant flow due to retardation	4.74E-04	m/d
Ratio of Compliance Point to Source Concentration	1.97E-01	fraction
Attenuation factor (C ₀ /C ₁₀)	5.07E+00	fraction

Remedial Targets

Level 3 Remedial Target	1.05E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₀ /C ₁₀	1.97E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.50E-03 fractionOrganic carbon partition coefficient K_{oc} 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

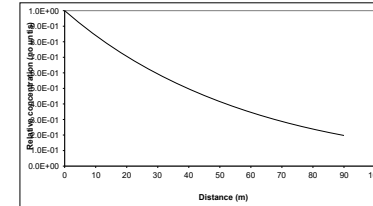
	ax	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	9.00E+00	4.18E+00	m
Transverse dispersivity	az	9.00E+00	9.00E-01	4.18E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	4.18E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	9.25E-01
9.0	8.55E-01
13.5	7.90E-01
18.0	7.31E-01
22.5	6.76E-01
27.0	6.25E-01
31.5	5.77E-01
36.0	5.33E-01
40.5	4.92E-01
45.0	4.54E-01
49.5	4.19E-01
54.0	3.86E-01
58.5	3.55E-01
63.0	3.27E-01
67.5	3.01E-01
72.0	2.77E-01
76.5	2.54E-01
81.0	2.34E-01
85.5	2.15E-01
90.0	1.97E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	6.29E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg
Factor (partitioning between soil and water)		1.06E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

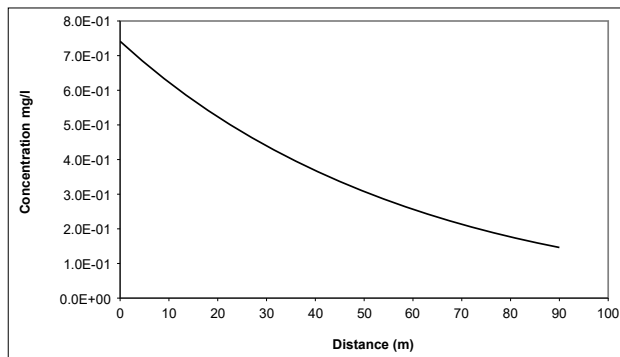
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.56E+00 mg/l	No dilution or attenuation
Level 2	C	7.41E-01 mg/l	Dilution taken into account
Level 3	C	1.46E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	7.41E-01
4.50	6.86E-01
9.00	6.34E-01
13.50	5.86E-01
18.00	5.42E-01
22.50	5.01E-01
27.00	4.63E-01
31.50	4.28E-01
36.00	3.95E-01
40.50	3.65E-01
45.00	3.37E-01
49.50	3.11E-01
54.00	2.86E-01
58.50	2.64E-01
63.00	2.43E-01
67.50	2.23E-01
72.00	2.05E-01
76.50	1.89E-01
81.00	1.73E-01
85.50	1.59E-01
90.00	1.46E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	3
Date:	01-Nov-22		
Contaminant	Fluoranthene		
Target Concentration (C _T)	6.00E-06	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant	Fluoranthene
Target concentration	0.000006 mg/l

Input Parameters	Variable	Value	Unit	Source of parameter value	
<i>Standard entry</i>					
Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	6.29E-05	dimensionless	Literature value	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
<i>Entry if specify partition coefficient (option)</i>					
Soil water partition coefficient	Kd		l/kg	Literature value	
<i>Entry for non-polar organic chemicals (option)</i>					
Fraction of organic carbon (in soil)	foc	5.80E-02	fraction	Site measurement for made ground	
Organic carbon partition coefficient	Koc	1.82E+04	l/kg	Literature value	
<i>Entry for ionic organic chemicals (option)</i>					
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg		
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg		
pH value	pH		pH units		
Acid dissociation constant	pKa				
Fraction of organic carbon (in soil)	foc		fraction		
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg	Calculated value	

Level 1 Remedial Target

Level 1 Remedial Target	6.33E-03	mg/kg	(for comparison with soil analyses)
	or		
	0.000006	mg/l	(for comparison with leachate test results)

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T **Fluoranthene**
0.000006 mg/l

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value
Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
Area of contaminant source	A	3.02E+03	m ²	Median of fill areas in Zone 2 Not used in calculation
Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas in Zone 2
Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 2 Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
		Calculate		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	1.12E+01	m	

Calculated Parameters

Dilution Factor	DF	3.45E+00		
Level 2 Remedial Target		2.07E-05 or 2.19E-02	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	01-Nov-22
Version:	3

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant	Cr	Fluoranthene		from Level 1
Target Concentration		0.000006	mg/l	from Level 1
Dilution Factor	DF	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	1.99E+03	days Pubchem
Calculated decay rate	λ	3.48E-04	days ⁻¹ calculated
Width of plume in aquifer at source	Sz	5.00E+01	m from Level 2
Plume thickness in aquifer at source	Sy	1.12E+01	m from Level 2
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³ Site measurement
Effective porosity of aquifer	n	2.30E-01	fraction Literature value
Hydraulic gradient	i	4.79E-02	fraction from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d from Level 2
Distance to compliance point	x	9.00E+01	m Median distance within Zone 2
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.73E+01	l/kg see options
Longitudinal dispersivity	ax	9.000	m see options
Transverse dispersivity	az	0.900	m see options
Vertical dispersivity	ay	0.090	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	2.50E+02 fraction
Decay rate used	λ	1.39E-06 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.79E-02 fraction
Rate of contaminant flow due to retardation	u	4.74E-04 m/d
Ratio of Compliance Point to Source Concentration	C _{EO} /C ₀	7.31E-01 fraction
Attenuation factor (C ₀ /C _{EO})	AF	1.37E+00 fraction

Remedial Targets

Level 3 Remedial Target	2.83E-05	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EO} /C ₀	7.31E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.50E-03 fraction

Organic carbon partition coefficient Koc 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,rel} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 2.73E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

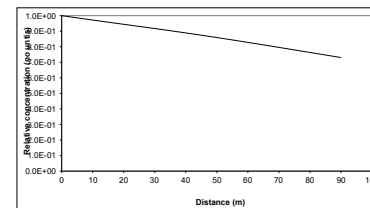
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	4.18E+00	m
Transverse dispersivity	az	9.00E+00	9.00E-01	4.18E-01 m
Vertical dispersivity	ay	9.00E+00	9.00E-02	4.18E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2/414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration
From calculation sheet	(No units)
Distance	concentration
0	1.0E+00
4.5	9.87E-01
9.0	9.75E-01
13.5	9.62E-01
18.0	9.50E-01
22.5	9.38E-01
27.0	9.25E-01
31.5	9.13E-01
36.0	9.00E-01
40.5	8.88E-01
45.0	8.74E-01
49.5	8.61E-01
54.0	8.47E-01
58.5	8.33E-01
63.0	8.19E-01
67.5	8.04E-01
72.0	7.89E-01
76.5	7.75E-01
81.0	7.60E-01
85.5	7.45E-01
90.0	7.31E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	3

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	6.29E-05	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.06E+03	l/kg
Factor (partitioning between soil and water)		1.06E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

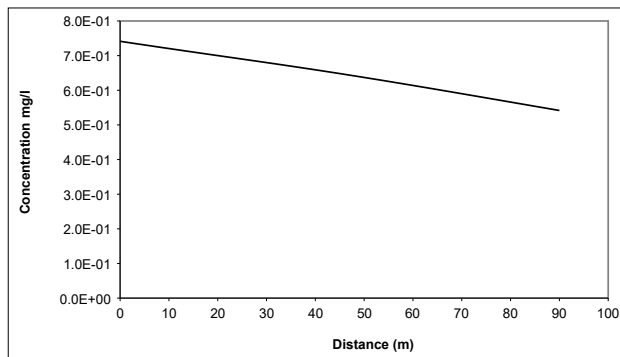
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.56E+00 mg/l	No dilution or attenuation
Level 2	C	7.41E-01 mg/l	Dilution taken into account
Level 3	C	5.42E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	7.41E-01
4.50	7.32E-01
9.00	7.23E-01
13.50	7.13E-01
18.00	7.04E-01
22.50	6.95E-01
27.00	6.86E-01
31.50	6.77E-01
36.00	6.68E-01
40.50	6.58E-01
45.00	6.48E-01
49.50	6.38E-01
54.00	6.28E-01
58.50	6.17E-01
63.00	6.07E-01
67.50	5.96E-01
72.00	5.85E-01
76.50	5.74E-01
81.00	5.63E-01
85.50	5.53E-01
90.00	5.42E-01



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	Lead		
Target Concentration (C _T)	0.00372	mg/l	Origin of C _T : EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Lead
Target concentration	0.00372 mg/l

Input Parameters
Standard entry

Water filled soil porosity	θ_w	3.12E-01	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	θ_a	1.52E-01	fraction	Calculated	
Bulk density of soil zone material	ρ	1.80E+00	g/cm ³	Site measurement for made ground	
Henry's Law constant	H	0.00E+00	dimensionless	N/A	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	1.00E+03	l/kg	Literature value
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Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 1.00E+03 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	3.72E+00	mg/kg	(for comparison with soil analyses)
	or		
	0.00372	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Lead
0.00372

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Median area of fill in zone 2 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill areas in Zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill areas in Zone 2 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.12E+01	m	

Calculated Parameters

Dilution Factor	DF	3.45E+00
Level 2 Remedial Target		1.28E-02 mg/l or 1.28E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Lead		from Level 1
Target Concentration	C _T	0.00372	mg/l	from Level 1
Dilution Factor	DF	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	1.12E+01	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.32E-01	fraction
Hydraulic gradient	i	4.79E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	9.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	K _d	1.00E+03	l/kg
Longitudinal dispersivity	ax	9.000	m
Transverse dispersivity	az	0.900	m
Vertical dispersivity	ay	0.090	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.18E-01
Retardation factor	R _f	9.14E+03
Decay rate used	λ	8.43E-105
Hydraulic gradient used in aquifer flow down-gradient	i	4.79E-02
Rate of contaminant flow due to retardation	u	1.29E-05
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.45E-01
Attenuation factor (C ₀ /C _{el})	AF	1.06E+00

Remedial Targets

Level 3 Remedial Target	1.36E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.45E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d 1.00E+03 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc}Organic carbon partition coefficient K_{oc}

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r}Sorption coefficient for ionised species K_{oc,i}

pH value pH

Acid dissociation constant pK_aFraction of organic carbon in aquifer f_{oc}Soil water partition coefficient K_d 1.00E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

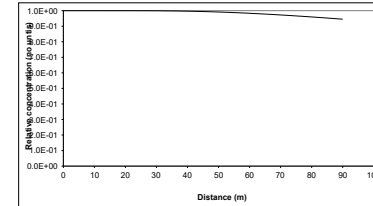
Enter value	Calc value	Xu & Eckstein	
ax	9.00E+00	9.00E+00	m
az	9.00E+00	9.00E-01	m
ay	9.00E+00	9.00E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	9.99E-01
36.0	9.98E-01
40.5	9.97E-01
45.0	9.94E-01
49.5	9.92E-01
54.0	9.88E-01
58.5	9.85E-01
63.0	9.80E-01
67.5	9.75E-01
72.0	9.70E-01
76.5	9.64E-01
81.0	9.58E-01
85.5	9.52E-01
90.0	9.45E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.00E+03	l/kg
Factor (partitioning between soil and water)		1.00E+03	dimensionless

Level 2 Parameters

Dilution Factor DF

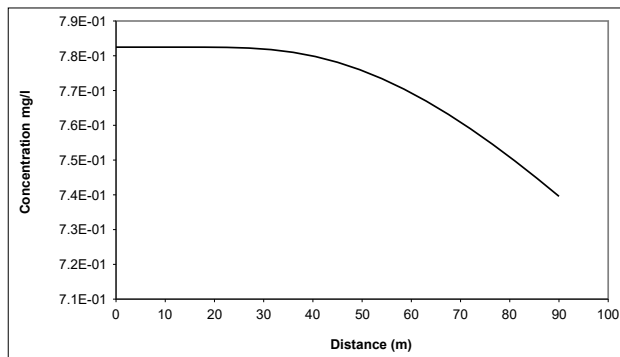
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	2.70E+00 mg/l	No dilution or attenuation
Level 2	C	7.82E-01 mg/l	Dilution taken into account
Level 3	C	7.40E-01 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	7.82E-01
4.50	7.82E-01
9.00	7.82E-01
13.50	7.82E-01
18.00	7.82E-01
22.50	7.82E-01
27.00	7.82E-01
31.50	7.82E-01
36.00	7.81E-01
40.50	7.80E-01
45.00	7.78E-01
49.50	7.76E-01
54.00	7.73E-01
58.50	7.70E-01
63.00	7.67E-01
67.50	7.63E-01
72.00	7.59E-01
76.50	7.55E-01
81.00	7.50E-01
85.50	7.45E-01
90.00	7.40E-01



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH	Version:	2
Date:	20-Oct-22		
Contaminant	Nickel		
Target Concentration (C _T)	0.0153	mg/l	Origin of C _T : BGS background concentration, 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Nickel
Target concentration	0.0153 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80	g/cm³	Site measurement for made ground	
Henry's Law constant	0.00	dimensionless	N/A	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	5.00E+02	l/kg	Literature value
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Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 5.00E+02 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	7.65E+00	mg/kg	(for comparison with soil analyses)
	or		
	0.0153	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration C_T

Nickel
0.0153 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.40E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Median area of fill in Zone 2 Not used in calculation
Entry for groundwater flow below site	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Median of fill in Zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Median of fill in Zone 2 Not used in calculation
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.12E+01	m	

Calculated Parameters

Dilution Factor	DF	3.45E+00
Level 2 Remedial Target		5.28E-02 mg/l or 2.64E+01 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Nickel		from Level 1
Target Concentration	C _r	0.0153	mg/l	from Level 1
Dilution Factor	DF	3.45E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
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Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	1.12E+01	m
Bulk density of aquifer materials	ρ	2.10E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.79E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	9.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	Kd	5.00E+02	l/kg
Longitudinal dispersivity	ax	9.000	m
Transverse dispersivity	az	0.900	m
Vertical dispersivity	ay	0.090	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	4.57E+03
Decay rate used	λ	1.69E-104 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.79E-02
Rate of contaminant flow due to retardation	u	2.60E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.45E-01
Attenuation factor (C ₀ /C _{el})	AF	1.06E+00

Remedial Targets

Level 3 Remedial Target	5.58E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.45E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 5.00E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc fraction

Organic carbon partition coefficient Koc l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc fraction

Soil water partition coefficient Kd 5.00E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

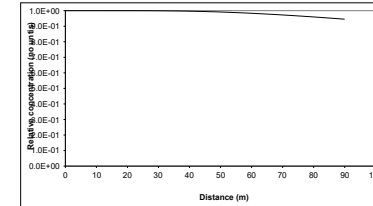
	Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	9.00E+00	9.12E+00	m
Transverse dispersivity	az	9.00E+00	4.18E-01	m
Vertical dispersivity	ay	9.00E+00	9.00E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	9.99E-01
36.0	9.98E-01
40.5	9.97E-01
45.0	9.94E-01
49.5	9.92E-01
54.0	9.88E-01
58.5	9.85E-01
63.0	9.80E-01
67.5	9.75E-01
72.0	9.70E-01
76.5	9.64E-01
81.0	9.58E-01
85.5	9.52E-01
90.0	9.45E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	5.00E+02	l/kg
Factor (partitioning between soil and water)		5.00E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

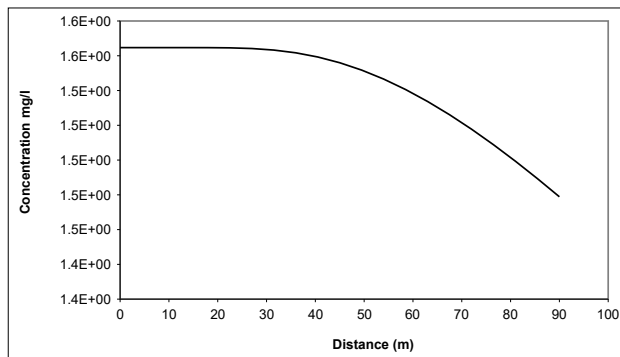
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	5.40E+00 mg/l	No dilution or attenuation
Level 2	C	1.56E+00 mg/l	Dilution taken into account
Level 3	C	1.48E+00 mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.56E+00
4.50	1.56E+00
9.00	1.56E+00
13.50	1.56E+00
18.00	1.56E+00
22.50	1.56E+00
27.00	1.56E+00
31.50	1.56E+00
36.00	1.56E+00
40.50	1.56E+00
45.00	1.56E+00
49.50	1.55E+00
54.00	1.55E+00
58.50	1.54E+00
63.00	1.53E+00
67.50	1.53E+00
72.00	1.52E+00
76.50	1.51E+00
81.00	1.50E+00
85.50	1.49E+00
90.00	1.48E+00



Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Victoria North HIF Infrastructure Works		
Site Address:	Re-use of fill in Zone 2		
Completed by:	DH		
Date:	20-Oct-22	Version:	2
Contaminant	Zinc		
Target Concentration (C _T)	0.1115	mg/l	Origin of C _T : BGS Baseline quality 95%ile

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2



Level 1 - Soil

Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Zinc
Target concentration	0.1115 mg/l

Input Parameters
Standard entry

Variable	Value	Unit	Source of parameter value	
Water filled soil porosity	0.312	fraction	Calculated	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.
Air filled soil porosity	0.152	fraction	Calculated	
Bulk density of soil zone material	1.80	g/cm ³	Site measurement for made ground	
Henry's Law constant	0.00	dimensionless	N/A	

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	5.01E+02	l/kg	Literature value
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Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg	
Sorption coefficient for ionised species	K _{oc,i}		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	

Soil water partition coefficient used in Level Assessment Kd 5.01E+02 l/kg Specified value

Level 1 Remedial Target

Level 1 Remedial Target	5.59E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.1115	mg/l	(for comparison with leachate test results)

Site being assessed: Victoria North HIF Infrastructure Works
Completed by: DH
Date: 20-Oct-22
Version: 2

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Zinc
0.1115 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Standard entry	Input Parameters	Variable	Value	Unit	Source of parameter value
	Infiltration	Inf	1.44E-03	m/d	Estimated based on 60% infiltration
	Area of contaminant source	A	3.02E+03	m ²	Calculated median area of fill in Zone 2
					Not used in calculation
	Length of contaminant source in direction of groundwater flow	L	6.30E+01	m	Calculated median length of fill in Zone 2
	Saturated aquifer thickness	da	1.50E+02	m	Literature value for Chester Pebble Beds
	Hydraulic Conductivity of aquifer in which dilution occurs	K	5.70E-01	m/d	Literature value
	Hydraulic gradient of water table	i	3.40E-02	fraction	Site measurement
	Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Calculated median width of fill in Zone 2
	Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
			Calculate		
	Enter mixing zone thickness	Mz		m	
	Calculated mixing zone thickness	Mz	1.13E+01	m	

Calculated Parameters

Dilution Factor	DF	3.41E+00
Level 2 Remedial Target		3.80E-01 mg/l or 1.91E+02 mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	20-Oct-22
Version:	2

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Zinc		from Level 1
Target Concentration	C _r	0.1115	mg/l	from Level 1
Dilution Factor	DF	3.41E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to dissolved pollutants only

Enter source concentration

Determine remedial target based on assumed concentration

Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	9.00E+99	days
Calculated decay rate	λ	7.70E-101	days ⁻¹
Width of plume in aquifer at source	Sz	5.00E+01	m
Plume thickness in aquifer at source	Sy	1.13E+01	m
Bulk density of aquifer materials	ρ	2.12E+00	g/cm ³
Effective porosity of aquifer	n	2.30E-01	fraction
Hydraulic gradient	i	4.81E-02	fraction
Hydraulic conductivity of saturated aquifer	K	5.70E-01	m/d
Distance to compliance point	x	9.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			
Partition coefficient	Kd	5.01E+02	l/kg
Longitudinal dispersivity	ax	4.183	m
Transverse dispersivity	az	0.418	m
Vertical dispersivity	ay	0.042	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.19E-01 m/d
Retardation factor	Rf	4.62E+03
Decay rate used	λ	1.67E-104 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	4.81E-02
Rate of contaminant flow due to retardation	u	2.58E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.96E-01
Attenuation factor (C ₀ /C _{el})	AF	1.00E+00

Remedial Targets

Level 3 Remedial Target	3.82E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	90	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{el} /C _s	9.96E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 5.01E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc

Organic carbon partition coefficient Koc

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,r}Sorption coefficient for ionised species K_{oc,i}

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 5.01E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

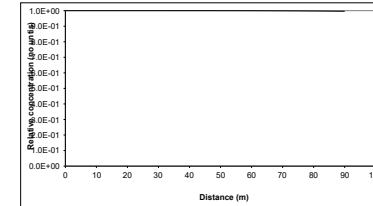
	Enter value	Calc value	Xu & Eckstein
Longitudinal dispersivity	ax	4.183	4.18E+00 m
Transverse dispersivity	az	0.418	4.18E-01 m
Vertical dispersivity	ay	0.042	4.18E-02 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration
0	1.0E+00
4.5	1.00E+00
9.0	1.00E+00
13.5	1.00E+00
18.0	1.00E+00
22.5	1.00E+00
27.0	1.00E+00
31.5	1.00E+00
36.0	1.00E+00
40.5	1.00E+00
45.0	1.00E+00
49.5	1.00E+00
54.0	1.00E+00
58.5	1.00E+00
63.0	9.99E-01
67.5	9.98E-01
72.0	9.98E-01
76.5	9.98E-01
81.0	9.98E-01
85.5	9.97E-01
90.0	9.96E-01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Victoria North HIF Infrastructure Works
Completed by:	DH
Date:	#####
Version:	2

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

Only input required is Soil Contaminant Concentration

Input Parameters
Soil contaminant concentration C_0 mg/kg

Level 1 Parameters

Water filled soil porosity	θ_w	3.12E-01	fraction
Air filled soil porosity	θ_a	1.52E-01	fraction
Bulk density	ρ	1.80E+00	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	5.01E+02	l/kg
Factor (partitioning between soil and water)		5.01E+02	dimensionless

Level 2 Parameters

Dilution Factor DF

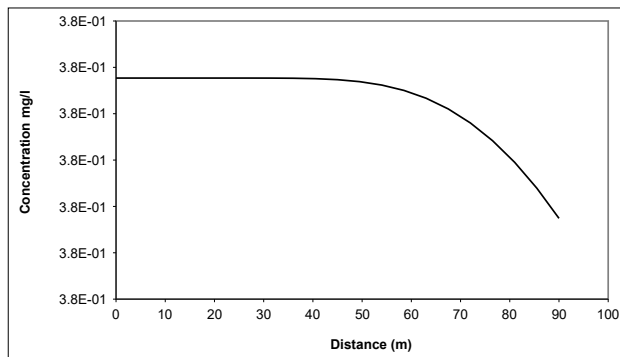
Level 3 Parameters

Attenuation factor (C_0/C_{ED}) AF

Predicted concentrations at compliance point

Level 1	C	1.29E+00	mg/l	No dilution or attenuation
Level 2	C	3.78E-01	mg/l	Dilution taken into account
Level 3	C	3.76E-01	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.78E-01
4.50	3.78E-01
9.00	3.78E-01
13.50	3.78E-01
18.00	3.78E-01
22.50	3.78E-01
27.00	3.78E-01
31.50	3.78E-01
36.00	3.78E-01
40.50	3.78E-01
45.00	3.78E-01
49.50	3.78E-01
54.00	3.78E-01
58.50	3.78E-01
63.00	3.78E-01
67.50	3.78E-01
72.00	3.78E-01
76.50	3.77E-01
81.00	3.77E-01
85.50	3.77E-01
90.00	3.76E-01

Appendix C

Groundwater sampling and monitoring

C.1 Groundwater sampling and monitoring

The table below summarises the groundwater sampling carried out as part of the 2022 BAM investigation, and includes notes where samples could not be obtained due to wells being dry.

Explo.-hole	Depth (m bgl)	East	North	Elevation (m AOD)	Response Zone	1 st round of groundwater sampling?	Notes in first round of sampling	2 nd round of groundwater sampling	Notes on second round of sampling	Sampling Rationale
BH101	7.8	384796.682	399802.989	43.377	Made ground		Y – was dry previously*		Dry – no samples possible	
BH102	8.5	384763.18	399691.375	42.934	Made ground/glacial till	Y		Y	Sampler notes sheen on water	
BH103	8.3	384689.014	399695.588	42.57	Made ground	Y		Y		Hydrocarbon odour in MG 0.1-1.3m
BH104	15	384607.46	399631.24	41.588	Made ground					
BH105	11.2	384463.735	399571.588	40.666	Made ground	Y		Y		
BH106	11.3	384459.989	399509.165	40.671	Made ground /till					
BH112	4.3	384401.713	399486.259	32.249	Made ground/Chester Pebble Beds					
BH201	9.3	384762.04	399820.851	43.4	Manchester Marl	Y		Y		Upgradient water quality (Marl)
BH202	9	384723.888	399716.141	42.663	Glacial till	Y		Y		
BH203	24	384845.747	399748.863	41.891	Collyhurst Sandstone	Y		Y		Inside river channel beneath gasworks. Moderate hydrocarbon odour 5.5-7.5m bgl
BH204	16.5	384815.474	399703.59	43.276	Made ground			Y		
BH205	10.8	384689.078	399735.153	42.578	Manchester Marl	Y		Y		Upgradient water quality (Marl)
BH206	6.8	384729.233	399690.75	42.692	Glacial till					
BH207	16.1	384654.246	399626.1	41.638	Made ground					
BH208	14.6	384562.98	399592.56	40.66	Made ground					
BH209	17	384548.843	399628.33	41.214	Chester Pebble Beds					
BH210	19.6	384479.67	399554.7	40.45	Chester Pebble Beds	Y	Dry – no samples possible	Y		In Chester Pebble Beds, upgradient
BH211A	11.6	384441.79	399513.96	40.44	Made ground			Y		Within old reservoir. Hydrocarbon odour 10.1-10.5m bgl
BH212	11.5	384487.32	399426.078	30.377	Chester Pebble Beds	Y		Y		
BH213	3.5	384475.449	399487.578	31.943	Made ground			Y	Dry – no samples possible	
BH214A	5	384430.619	399360.713	30.033	Glacial till					
WS201B	1.65	384735.29	399787.2	43.55	Made ground					
WS207	5	384628.92	399674.79	41.91	Made ground					
WS208	4.65	384566	399473	30.168						
BH301	15.08	384852.11	399762.18	41.87						
BH302	14.08	384826.9	399705.6	42.76						
BH303	12.7	384719.84	399660.22	42.3	Alluvium			Y		
BH304	16.7	384618.46	399600.49	41.18	Made ground					
BH305	12.03	384525.98	399549.39	39.77	Made ground					
BH306	6.3	384520.14	399490.63	31.45	Alluvium	Y		Y		Strong hydrocarbon odour 1.8-3.9m bgl
BH307	5	384461.01	399430.12	30.61	Made ground					
BH309	11.5	384863.87	399641.32	30.5	Chester Pebble Beds					
BH310	16	384838.09	399638.18	32.6	Chester Pebble Beds	Y		Y		Weak hydrocarbon odour 8.2-9.3m bgl
BH311	17.32	384411.7	399557.68	46.2	Glacial till					
BH312	16.82	384382.83	399519.93	45.6	Made ground					
BH313	12.4	384395.83	399507.84	39.81	Glacial till					
BH314	12.45	384439.7	399502.02	43.11	Glacial till/Chester Pebble Beds	Y		Y		Strong hydrocarbon odour 8.2 to 9.3m bgl

Explo.-hole	Depth (m bgl)	East	North	Elevation (m AOD)	Response Zone	1 st round of groundwater sampling?	Notes in first round of sampling	2 nd round of groundwater sampling	Notes on second round of sampling	Sampling Rationale
BH315	13.52	384852.04	399729.3	39.26	Alluvium	Y		Y		
BH320	6.7	384889.76	399761.36	34.26	Alluvium		Y – was dry previously*		Dry – no samples possible	Alluvium in river channel. Strong hydrocarbon odour 4.4-5.6m bgl
BH321	6	384770.34	399639.02	34.2	Made Ground	Y		Y*	Dry – no samples possible	
BH322	6	384715.2	399587.28	32.49	Alluvium	Y		Y*	Dry – no samples possible	Weak hydrocarbon odour 0.9-3.25m bgl
BH323	2.6	384658.4	399576.88	30.21	Made ground					
BH324	15.3	384593.99	399584.6	41	Alluvium					
BH325	4.5	384446.11	399359.16	29.95	Made ground					
RE15	15	384476.01	399396.98	30.17				Y		Offsite but in sandstone, downgradient of site @ Union Bridge, drilled for river works
TT301	N/A				Made ground			Y		Groundwater taken from an open trial trench dug within the former gasworks site, where there was evidence of hydrocarbon contamination of perched groundwater