Compass Geotechnical
Geotechnical, Geoenvironmental and Civil Engineering Consultants

REPORT ON DERIVATION OF REMEDIATION TARGETS FOR GROUNDWATER CONTAMINATION AT FORMER CHAMBERS BUS DEPOT, CHURCH SQUARE, BURES, SUFFOLK, CO8 5AB

Report No: 222945RTM

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Compass Geotechnical Limited
13 Willow Park, Upton Lane, Stoke Golding, Warwickshire, CV13 6EU
Tel: 01455 213311: Fax: 01455 213969
Email: enquiries@compassgeotechnical.co.uk
www.compassgeotechnical.co.uk

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Report Prepared For:
Rose Builders Limited
Riverside House
Riverside Avenue East
Lawford
Essex
CO11 1US

Report Prepared By:
Compass Geotechnical Limited
13 Willow Park
Upton Lane
Stoke Golding
CV13 6EU

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REPORT ON DERIVATION OF REMEDIATION TARGETS FOR GROUNDWATER CONTAMINATION AT FORMER CHAMBERS BUS DEPOT, CHURCH SQUARE, BURES, SUFFOLK, CO8 5AB

1. INTRODUCTION AND OBJECTIVES

1.1 This report has been prepared on instructions given by the Client, Rose Builders Limited (Riverside House, Riverside Avenue East, Lawford, Essex, CO11 1US).

1.2 The site is located on the north eastern side of High Street and immediately to the north of the B1508 (Church Square) in the north of the village of Bures, Suffolk as shown on Figure 1, Appendix (i). Bures lies approximately 9km to the south of Sudbury and 16km to the north west of Colchester. As shown on Figure 2, Appendix (i), the site is irregular in shape comprising a number of buildings and areas of hard standing formerly used as a bus depot. The site is at and around National Grid Reference 590750, 124090 and covers an area of around 0.32ha (Reference 1).

1.3 The site has been the subject of a previous desk study, intrusive investigations and assessments as referenced below:

- Compass Geotechnical Limited Report on a Phase 1 Desk Study and Risk Assessment for A Proposed Mixed-Use Development at Former Chambers Bus Depot, Church Square, Bures, Suffolk, CO8 5AB. Report No: 212945A dated September 2021.
- Compass Geotechnical Limited Report on a Phase 2 Ground Investigation and Contamination Assessment for a Proposed Mixed-Use Development at Former Chambers Bus Depot, Church Square, Bures, Suffolk, CO8 5AB. Report No: 212945B dated June 2022.
- Compass Geotechnical Limited Report on a Supplementary Geotechnical Investigation for a Proposed Mixed-Use Development at Former Chambers Bus Depot, Church Square, Bures, Suffolk, CO8 5AB. Report No: 222945S dated August 2022.
- Compass Geotechnical Limited Letter Report on Ongoing Groundwater Monitoring – Former Chambers Bus Garage, Bures. Reference 222945L-1 dated 3rd January 2023.
- Compass Geotechnical Limited Letter Report on Hydrocarbon Vapour Intrusion Assessment - Former Chambers Bus Garage, Bures. Report No: 222945L-2 dated 27th January 2023.

In addition, outline proposals for remediation of the site have been drawn up in the following document:

- Compass Geotechnical Limited Remediation Method Statement for a Proposed Mixed-Use Development at Former Chambers Bus Depot, Church Square, Bures, Suffolk, CO8 5AB. Report No: 222945RMS dated January 2023.

1.4 Proposals are to redevelop the front (west) section of the site for retail/commercial use with residential above and housing with private gardens to the rear (east). A plan showing the proposed layout is presented as Figure 3, Appendix (i).

1.5 Following submission of the Phase 2 Ground Investigation and Contamination Assessment Report and the Remediation Method Statement to the Environment Agency (EA) additional information was requested by the EA in relation to the presence of hydrocarbons in the soils and groundwater in the south western corner of the site thought to be associated with the presence of an old below ground fuel tank.

The aims of this current assessment are to derive remediation targets for both soils and groundwater in the south western corner which would be protective of the groundwater environment and is based on the results and findings of the previous investigations along with more recent works including:

- Recovery and analysis of groundwater samples in April 2023 to provide data on current concentrations of hydrocarbons in groundwater.
- Data from monthly monitoring of groundwater levels at the site from February 2022 and March 2023.
- Survey data provided by the Client.

1.6 The investigation, assessment and reporting has been carried out in general accordance with the following:

- BS 5930:2015+A1:2020. Code of Practice for Ground Investigations.
- BS EN ISO 14688-1:2018. Geotechnical investigation and testing – Identification and classification of a soil – Part 1: Identification and description.
- BS EN ISO 14688-2:2018. Geotechnical investigation and testing – Identification and classification of a soil – Part 2: Principles for a classification.
- BS EN ISO 22476-2:2005+A1:2011. Geotechnical investigation and testing – Field testing – Part 2: Dynamic Probing.
- BS EN ISO 22476-3:2005+A1:2011. Geotechnical investigation and testing – Field testing – Part 3: Standard Penetration Test.
- BS EN ISO 14689:2018. Geotechnical investigation and testing – Identification and classification of rock – Part 1: Identification and description.
- BS EN ISO 22475-1:2006. Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution.
- BS 1377-9:1990. Soils for civil engineering purposes – Part 9 In-situ tests.
- BS EN 1997-1:2004+A1:2013 Eurocode 7: Geotechnical design – Part 1: General Rules.
- NA to BS EN 1997-1:2004+A1:2013. UK National Annex to Eurocode 7: Geotechnical design – Part 1: General Rules.
- BS EN 1997-2:2007. Eurocode 7: Geotechnical design – Part 2: Ground investigation and testing.
- NA to BS EN 1997-2:2007. UK National Annex to Eurocode 7: Geotechnical design – Part 2: Ground investigation and testing.

- Environment Agency (2006) Remedial Targets Methodology. Hydrogeological Risk Assessment for Land Contamination.
- BS 10175:2011+A2:2017. Investigation of Potentially Contaminated Sites – Code of Practice.
- BS 8576:2013 Guidance on Investigations for ground gases – Permanent gases and Volatile Organic Compounds (VOCs).
- BS 8485:2015 + A1:2109. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.
- Environment Agency (2018). The Environment Agency's Approach to Groundwater Protection, Version 1.2.

2. SITE LOCATION AND SETTING

2.1 The area under consideration is located in the centre of Bures, Suffolk and is accessed from Church Square in the south western corner via a concrete accessway leading to a large gate beyond which is the main yard area. To the north of the accessway is a complex of buildings including the main bus garage and workshop and Knowle House which includes offices and living accommodation. Inside the main garage are inspection pits and a hydraulic bus lift. An annotated plan showing the main features of the site is presented as Figure 4, Appendix (i).

In the rear yard a further hydraulic bus lift and inspection pit are present along with a bus wash with associated water tank and pump, and interceptors. It is known that a second bus wash, now buried, is present in the yard on the southern side of the existing bus wash. Storage buildings and lean-to structures are present along the southern side of the yard.

A below ground fuel tank is present in the south western corner of the site close to Knowle House. A further two below ground fuel tanks may be present in the main bus garage. It is understood that two above ground fuel tanks were present at the site, one internal to the bus garage and one external along with the base for a fuel pump and associated pipe work. Further possible tanks and other below ground features have been identified by ground probing radar (GPR) and are also shown on Figure 4, Appendix (i).

2.2 The site is underlain by natural superficial River Terrace deposits overlying solid strata of the Thanet Formation and Lambeth Group (undifferentiated) which in turn overlie the Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated). The geological map suggests the chalk outcrops in the west of the site. The superficial deposits are classed as a Secondary A Aquifer, the bedrock is designated as a Principal Aquifer and the site lies in a groundwater protection zone – Total Catchment Zone 3.

3. FINDINGS OF THE PREVIOUS INVESTIGATIONS AND ASSESSMENTS

3.1 It is believed that most of the site was owned by H Chambers from at least 1877. Originally, the site was operated as a horse drawn bus service but also rented out horses and traps, provided livery stables and ran a saddlery business. Motorised buses were operated from 1918 onwards and it is believed that Chambers also operated a haulage business, however the depot has not been used by buses since approximately 2012. The historical maps obtained as part of the desk study indicate that the site was initially developed with several buildings to the west adjacent to the road and in the north west with an enclosed field with isolated trees to the east. A fire in 1927 destroyed some of the buildings, which were replaced with the large workshop structure currently present.

A 500 gallon petrol tank was installed at the site in 1922 and this is thought to have been towards or in the south western corner. Further information from Trading Standards, Suffolk County Council, suggests that the petrol tank was converted to diesel in 1971 and the tank position has been located by GPR close to Knowle House and the current site entrance.

3.2 The investigations undertaken by Compass Geotechnical Limited confirmed the presence of made ground across the entire site underlain by some disturbed ground overlying natural sands and gravels extending to around 7.0m bgl in the central and eastern sections of the site and around 13m bgl in the west. The sands and gravels (River Terrace Deposits) are thought to overlie solid strata of the Thanet Formation and Lambeth Group which were proved to the full depth of the investigation (15.0m bgl). It is considered that the upper surface of the Thanet Formation and Lambeth Group forms a stepped or terraced profile across the site cut by river action in the geological past giving rise to the variation in thickness of the overlying River Terrace Deposits observed in the boreholes. From records of boreholes nearby it is thought that the clays and silts of the Thanet Formation and Lambeth Group are of limited thickness and may only extend to around 19.5m bgl below which the chalk is present.

Reference should be made to the reports of section 1.3 for full details of the site, the investigations carried out, ground conditions encountered and the available test results.

3.3 The investigations have highlighted elevated levels of lead, PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene and dibenz(ah)anthracene) and localized TPH and asbestos in the made ground across the site. In addition, the made ground in the central and eastern parts of the site contains large concrete obstructions, bus parts and other visually unsuitable materials.

In the natural soils, evidence of hydrocarbon contamination was found in the south western corner close to the location of the known below ground fuel tank. Samples of the groundwater were recovered on two occasions in March 2022 and analysis indicated the presence of diesel in both the soils and the groundwater. Although the contamination appeared to be of limited lateral extent and depth.

Due to the complex nature of the site and the presence of numerous buildings and large areas of hard standing it is possible that further, as yet unidentified, areas of contamination are present.

4. RECENT SITE WORK

4.1 Regular monitoring of groundwater levels across seven monitoring points has been carried out since February 2022. The groundwater monitoring results are presented in Appendix (ii) along with plots of groundwater elevation over time and a plan showing the location of all of the exploratory holes undertaken is included as Figure 5, Appendix (i).

4.2 To obtain information on the current concentration of hydrocarbons in the groundwater, samples were recovered from BHA to BHD on 29th March 2023 using dedicated low flow sampling techniques to prevent cross contamination. The groundwater samples were recovered in amber glass Winchester bottles and vials and delivered to the laboratory on the same day for analysis.

4.3 Permeability testing was undertaken as falling head tests in BHE and BHG on 29th March 2023. The results of the falling head tests are presented in Appendix (iii) along with calculations and assessment of permeability in accordance with BS EN ISO 22282-1:2012 and BS EN ISO 22282-2:2012. The groundwater flow direction and hydraulic gradient have been calculated from the groundwater level monitoring results.

5. RECENT LABORATORY WORK

5.1 Detailed below in Table 5.1 is the more recent analysis undertaken on samples of the groundwater:

Table 5.1 Summary of Groundwater Analysis – March 2023

Contamination Test	Number of Tests Groundwater
TPH CWG	4
BTEX and MTBE	4
SVOC (speciated)	2

5.2 The results of the recent laboratory testing are presented in Appendix (iv) and discussed in Sections 6 and 8.

5.3 The laboratory testing was undertaken during the period 29th March and 11th April 2023.

5.4 The testing was undertaken at a UKAS and MCERTS accredited laboratory.

6. DISCUSSION OF HYDROCARBON RESULTS

6.1 Hydrocarbons in Soils

Hydrocarbon impacted soils were identified by visual and olfactory means in WS4, BHA and BHB of the previous investigations which were located in proximity to the below ground fuel tank in the south western corner of the site. No evidence of hydrocarbon impacted soils were found elsewhere at the site. The relevant results are summarized in Table 6.1 below and from the chromatograms the laboratory has confirmed that the hydrocarbons present represent diesel. Table 6.1 also includes results from BHC and BHD, located away from the below ground tank, which indicates no hydrocarbon impacted soils in these positions.

Table 6.1 Summary of TPH CWG Analysis – Natural Soils

Determinand	WS4 1.0-1.1m mg/kg	WS4 1.65-1.85m mg/kg	WS4 2.15-2.2m mg/kg	BHA 3.0m mg/kg
Aliphatic TPH >C5-C6	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C6-C8	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C8-C10	< 1.0	< 1.0	280	< 1.0
Aliphatic TPH >C10-C12	3.0	160	780	< 1.0
Aliphatic TPH >C12-C16	190	710	2900	410
Aliphatic TPH >C16-C21	230	1000	3700	430
Aliphatic TPH >C21-C35	< 1.0	400	1300	< 1.0
Aliphatic TPH >C35-C44	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C5-C7	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C7-C8	< 1.0	< 1.0	38	< 1.0
Aromatic TPH >C8-C10	< 1.0	< 1.0	53	< 1.0
Aromatic TPH >C10-C12	< 1.0	100	560	< 1.0
Aromatic TPH >C12-C16	< 1.0	340	2100	48
Aromatic TPH >C16-C21	< 1.0	< 1.0	1100	< 1.0
Aromatic TPH >C21-C35	< 1.0	< 1.0	520	< 1.0
Aromatic TPH >C35-C44	< 1.0	< 1.0	< 1.0	< 1.0

Determinand	BHA 4.0m mg/kg	BHA 5.0m mg/kg	BHB 3.5m mg/kg	BHB 4.0m mg/kg
Aliphatic TPH >C5-C6	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C6-C8	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C8-C10	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C10-C12	120	< 1.0	< 1.0	22
Aliphatic TPH >C12-C16	880	< 1.0	< 1.0	44

Determinand	BHA 4.0m mg/kg	BHA 5.0m mg/kg	BHB 3.5m mg/kg	BHB 4.0m mg/kg
Aliphatic TPH >C16-C21	1000	< 1.0	< 1.0	33
Aliphatic TPH >C21-C35	130	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C35-C44	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C5-C7	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C7-C8	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C8-C10	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C10-C12	38	< 1.0	< 1.0	< 1.0
Aromatic TPH >C12-C16	280	< 1.0	< 1.0	< 1.0
Aromatic TPH >C16-C21	70	< 1.0	< 1.0	< 1.0
Aromatic TPH >C21-C35	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C35-C44	< 1.0	< 1.0	< 1.0	< 1.0

Determinand	BHB 4.5m mg/kg	BHB 6.0m mg/kg	BHC 3.5m mg/kg	BHD 3.5m mg/kg
Aliphatic TPH >C5-C6	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C6-C8	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C8-C10	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C10-C12	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C12-C16	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C16-C21	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C21-C35	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C35-C44	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C5-C7	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C7-C8	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C8-C10	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C10-C12	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C12-C16	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C16-C21	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C21-C35	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C35-C44	< 1.0	< 1.0	< 1.0	< 1.0

The results suggest that the highest concentrations of hydrocarbon impacted soils are present in WS4 and BHA, closest to the location of the below ground fuel tank, at depths between 1.0 and 4.0m depth consistent with observations on site. Little hydrocarbon contamination was identified in BHB and no impacted soils were found in BHC or BHD located around 20 and 27m from the tank location. BHB is approximately 11m from the tank whereas BHA and WS4 are around 4 to 5m from the tank.

The observed pattern of hydrocarbon bands in the soils is reasonably consistent between the boreholes and the laboratory has confirmed the hydrocarbons represent diesel which typically consists of hydrocarbons in the range C8-C21. The observed highest concentrations are typically in the following bands: Aliphatic C12-C16, Aliphatic C16-C21 and Aromatic C12-C16. In terms of the potential mobility the aliphatic C12-C16 and C16 to C21 bands are ranked as very low (Reference 3) and the aromatic C12-C16 are considered moderate. Very few of the more mobile hydrocarbon bands have been detected in the soils tested.

6.2 Hydrocarbons in Groundwater

The initial sampling and testing of the groundwater was carried out in spring 2022 with samples recovered by dedicated inertia pumps. The results of the first two rounds of groundwater testing are summarized in Table 6.2 below and indicate some relatively high concentrations of hydrocarbons.

Table 6.2 Groundwater Monitoring 23 February 2022

Determinand	BHA µg/l	BHB µg/l	BHC µg/l	BHD µg/l
Aliphatic TPH >C5-C6	160	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C6-C8	670	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C8-C10	320	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C10-C12	3000	450	< 0.10	< 0.10
Aliphatic TPH >C12-C16	18000	2700	< 0.10	< 0.10
Aliphatic TPH >C16-C21	24000	3200	< 0.10	< 0.10
Aliphatic TPH >C21-C35	8300	1500	1400	< 0.10
Aliphatic TPH >C35-C44	< 0.10	< 0.10	< 0.10	< 0.10
Total Aliphatic Hydrocarbons	54000	7900	1400	< 5.0
Aromatic TPH >C5-C7	270	< 0.10	< 0.10	< 0.10
Aromatic TPH >C7-C8	310	< 0.10	< 0.10	< 0.10
Aromatic TPH >C8-C10	860	< 0.10	< 0.10	< 0.10
Aromatic TPH >C10-C12	2200	250	< 0.10	< 0.10
Aromatic TPH >C12-C16	20000	2500	< 0.10	< 0.10
Aromatic TPH >C16-C21	21000	2800	< 0.10	< 0.10
Aromatic TPH >C21-C35	2700	< 0.10	< 0.10	< 0.10
Aromatic TPH >C35-C44	< 0.10	< 0.10	< 0.10	< 0.10
Total Aromatic Hydrocarbons	47000	5500	< 5.0	< 5.0
Total Petroleum Hydrocarbons	100000	13000	1400	< 10
Benzene	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0	< 1.0
m & p-Xylene	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	< 1.0	< 1.0	< 1.0	< 1.0
Methyl Tert-Butyl Ether	< 1.0	< 1.0	< 1.0	< 1.0

Table 6.2 Groundwater Monitoring 4 March 2022

Determinand	BHA µg/l	BHB µg/l	BHC µg/l	BHD µg/l
Aliphatic TPH >C5-C6	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C6-C8	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C8-C10	55	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C10-C12	670	260	< 0.10	< 0.10
Aliphatic TPH >C12-C16	3800	1900	< 0.10	< 0.10
Aliphatic TPH >C16-C21	4700	2500	< 0.10	< 0.10
Aliphatic TPH >C21-C35	2300	1300	< 0.10	< 0.10
Aliphatic TPH >C35-C44	< 0.10	< 0.10	< 0.10	< 0.10
Total Aliphatic Hydrocarbons	12000	6000	< 5.0	< 5.0
Aromatic TPH >C5-C7	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C7-C8	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C8-C10	210	< 0.10	< 0.10	< 0.10
Aromatic TPH >C10-C12	610	190	< 0.10	< 0.10
Aromatic TPH >C12-C16	4900	1900	< 0.10	< 0.10
Aromatic TPH >C16-C21	4900	2200	< 0.10	< 0.10
Aromatic TPH >C21-C35	1300	560	< 0.10	< 0.10
Aromatic TPH >C35-C44	< 0.10	< 0.10	< 0.10	< 0.10
Total Aromatic Hydrocarbons	12000	4900	< 5.0	< 5.0
Total Petroleum Hydrocarbons	23000	11000	< 10	< 10
Benzene	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0	< 1.0
m & p-Xylene	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	< 1.0	< 1.0	< 1.0	< 1.0
Methyl Tert-Butyl Ether	< 1.0	< 1.0	< 1.0	< 1.0

The results confirm the presence of elevated levels of hydrocarbons in the groundwater in BHA and BHB in the south western corner close to the below ground fuel tank. There was no evidence of hydrocarbons in BHD and very low levels of low mobility aliphatic hydrocarbons were detected in BHC on the first round of monitoring only.

The laboratory chromatogram confirms that the hydrocarbons in BHA and BHB are diesel and the pattern of results is similar to that observed in the soils in BHA and WS4 located close to the below ground fuel tank.

Summarised in Table 6.3 below are the results of the most recent groundwater sampling carried out in March 2023 using low flow sampling techniques. Testing was also carried out for SVOCs to identify any other substances of potential concern (Reference 3) and highlight drivers for the hydrogeological risk assessment. No SVOCs were identified in the samples tested from BHA and BHB.

Table 6.3 Groundwater Monitoring 29th March 2023

Determinand	BHA µg/l	BHB µg/l	BHC µg/l	BHD µg/l
Aliphatic TPH >C5-C6	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C6-C8	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C8-C10	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C10-C12	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C12-C16	< 0.10	440	< 0.10	< 0.10
Aliphatic TPH >C16-C21	< 0.10	1200	< 0.10	< 0.10
Aliphatic TPH >C21-C35	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C35-C44	< 0.10	< 0.10	< 0.10	< 0.10
Total Aliphatic Hydrocarbons	< 5.0	1700	< 5.0	< 5.0
Aromatic TPH >C5-C7	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C7-C8	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C8-C10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C10-C12	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C12-C16	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C16-C21	< 0.10	250	< 0.10	< 0.10
Aromatic TPH >C21-C35	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C35-C44	< 0.10	< 0.10	< 0.10	< 0.10
Total Aromatic Hydrocarbons	< 5.0	250	< 5.0	< 5.0
Total Petroleum Hydrocarbons	< 10	1900	< 10	< 10
Benzene	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0	< 1.0
m & p-Xylene	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	< 1.0	< 1.0	< 1.0	< 1.0
Methyl Tert-Butyl Ether	< 1.0	< 1.0	< 1.0	< 1.0

The most recent results indicate the presence of hydrocarbons in the sample from BHB only and the concentrations are relatively low with a concentration of total TPH of around 1.9mg/l. These results are considered more representative of the actual groundwater conditions than indicated by the initial sets of results (Tables 6.1 and 6.2) and it should be noted that the hydrocarbon bands present are those deemed by Reference 3 to be of low and very low overall relative mobility in groundwater and perhaps suggest the presence of residual contamination only.

7. GROUNDWATER CONDITIONS

7.1 Monitoring of groundwater levels in seven locations across the site over the last year has indicated depths to groundwater of between 2.72 and 4.83m bgl. The plots included in Appendix (ii) show seasonal changes in groundwater levels with higher levels encountered during the winter period and lower levels in summer as would be expected. It should be noted that in November 2022 the ground around WSE was disturbed as part of the archaeological investigation and the readings of groundwater levels taken on 23rd November 2022 are not considered representative and should be disregarded.

A plot of groundwater elevation over time is also presented in Appendix (ii), which again illustrates seasonal changes and also the effect of the particularly dry February in 2023. Overall groundwater elevation varied between 17.9m AOD and 16.7m AOD during the monitoring period. The plot also illustrates that there is little difference between the groundwater elevation in any of the monitoring points. However, generally the highest levels were recorded in BHG and the lowest in BHB.

7.2 Based on the site measurements the groundwater flow direction is assessed as to the south east (114° to 136° south of east), with a relatively shallow hydraulic gradient of around 0.0018 to 0.0037.

7.3 Falling head permeability tests were carried out in BHE and BHG away from the areas of contamination. The tests give permeability of between 1.6 x 10^{-3} and 6 x 10^{-4} m/s which is considered appropriate for sand and gravels (River Terrace Deposits). Initial estimates based on laboratory particle size distributions and Hazen's formula also suggest permeability of the order of 2.2 x 10^{-4} m/s.

8. REMEDIATION TARGETS METHODOLOGY ASSESSMENT

8.1 Analysis of Remedial Targets

In line with the requirements of the Environment Agency, assessments have been undertaken for groundwater resources in order to assess the possible impact of the contamination and derive remediation targets to minimise the impact and be protective of the groundwater. The assessments have been made in accordance with the Environment Agency Remedial Targets Methodology (Reference 2). The procedures adopted involve determination of remediation target concentrations for contaminants within soils and groundwater which would safeguard water resources down hydraulic gradient from the contamination source both on site and off site. There are no nearby groundwater abstraction points down hydraulic gradient from the site. The closest Public Water Supply boreholes lie to the south east (around 1376m distant) and to the north (1649m distant). The contamination identified at the site is within the River Terrace Deposits and does not appear to persist with depth.

The closest surface water course is the River Stour, a short distance to the south west and west. However, the groundwater flow direction does not appear to be towards the River Stour.

The Remedial Targets Methodology (RTM) is a tiered appraisal. Tier 1 assesses the possibility of contamination within the soils leaching out into the groundwater. Tier 2 considers the effects of dilution of contamination by the volume of groundwater flowing beneath the site, should contaminants reach the groundwater. Tier 3 assumes contamination has reached the groundwater and represents a further refinement of the model. Tier 3 allows consideration of the effects of attenuation and natural decay on the contamination and is used to determine remediation targets for contamination within the soils and in the groundwater itself. As the groundwater at the site has been impacted, at least locally, by hydrocarbons a Tier 3 analysis has been carried out for both soils and groundwater. The calculation sheets are presented in Appendix (v) and include the Tier 1 and Tier 2 analysis which are necessary to complete the Tier 3 analysis.

The groundwater testing undertaken has indicated the presence of concentrations of hydrocarbons, notably in BHA and BHB closest to and down hydraulic gradient from the below ground tank in the south west corner of the site. As discussed in Section 6 the hydrocarbons present in the soils and groundwater are diesel and the pattern suggests that only the less mobile fractions appear to remain in the groundwater. Although other below ground and above ground fuel tanks are present or were present at the site no other hydrocarbon impact on soils or groundwater has been identified and the following assessment is concerned only with the observed contamination in the south west of the site associated with the below ground fuel tank. However, other as yet unknown hydrocarbon contamination may be present at the site.

The following analyses and derivation of remediation targets use the most recent set of groundwater monitoring results which are considered representative of current conditions on site. The recent results suggest the presence of hydrocarbons in three carbon ranges in the groundwater.

The calculations rely on soil/water partition coefficients to assess the proportion of the contaminant that could move freely from soils to groundwater. In assessing petroleum hydrocarbons the soil/water partition coefficients vary widely depending on carbon banding and whether aromatic or aliphatic hydrocarbons are present. As there is not considered to be a representative value for the soil/water partitioning coefficient, which would be applicable to a total measure of hydrocarbons, the analysis has considered closely banded aromatic and aliphatic hydrocarbons separately.

The parameters used in the calculations are based, where possible, on actual site and laboratory measurements. Where measured parameters are not available published data has been utilised. The physio-chemical parameters adopted are given in the calculation sheets of Appendix (v). Where possible, if there are uncertainties, sensitivity analysis has been used to assess the significance of varying or using a range of values for individual parameters and usually a worst case has been adopted. The parameters which have the greatest influence on the calculations are the infiltration rate, permeability and hydraulic gradient and thus careful consideration has been given to the selection of these parameters. Individual cases are discussed further in the following sections.

The selection of an appropriate target concentration in the analysis is fundamental. The target is a concentration at a compliance point that should not be exceeded. Where the compliance point is the receptor, current guidance available on the UK Government web site suggests that the target concentration should be the relevant environmental standard or background groundwater quality. However, there are no published UK guideline values specifically for contaminants in groundwater, few environmental quality standards and the Environment Agency Chemical Standards Database was withdrawn on 6th January 2023. In the absence of relevant standards, the UK drinking water standards or World Health Organization (WHO) drinking water guide values could be used.

It is recognised however, that the UK drinking water standards relate to the total measure of petroleum hydrocarbons (excluding BTEX). The most recent monitoring has identified the presence of hydrocarbons currently in three carbon ranges in the groundwater. Thus, the target values for TPH used in the calculations for each carbon band relate to one third of the adopted standard; where the UK drinking water standard is used for the initial appraisals as this is a particularly stringent method of analysis. The WHO guide values relate to the individual carbon fractions.

The assessments have been based on a compliance point located initially at 40m and subsequently at 15m down hydraulic gradient from the location of the below ground tank. The initial runs were to assess the overall validity of the model and parameters selected. For derivation of the target concentrations the compliance point was set at 15m which is approximately the distance to the site boundary.

The recommended scenario for RTM analysis (Ogata Banks) assumes that there is a continuous and continuing source of pollution which leads to steady state conditions and thus gives rise to reasonably conservative target concentrations which are protective of the groundwater environment. The RTM analysis also allows modelling of a time-dependent scenario (Domenico) where there is a depleting source term or where the contaminant has entered the system relatively recently. The use of time dependent scenarios can lead to an over-estimation of target concentrations and is not recommended for the derivation of remediation targets but can be used to check the validity of the model and assumptions made. In the case being assessed it is known that the below ground tank was converted to diesel in approximately 1971 and has not been in use for some time. Thus, any contamination is not being replenished, it is thought that the contamination entered the groundwater sometime in the last 50 years and the source term is depleting. However, in line with the recommended approach the Ogata Banks scenario has been used to derive targets for remediation.

8.2 Discussion of Remedial Targets

Remediation targets for the contaminants of concern have been calculated using the analysis as detailed in Section 8.1. Individual Tier 3 targets for soils and Tier 3 targets for groundwater have been determined for each of the three hydrocarbon bands and splits detected recently in the groundwater in BHB. The target concentrations for soils for TPH aromatic C16-C21 appear to be more critical than those calculated for the aliphatic fractions and the model has been run a number of times for TPH aromatic C16-C21 with each run representing a refinement of the model varying parameters to more accurately assess conditions on site including time-dependent scenarios. Only the most relevant runs are presented in Appendix (v) however, for completeness all of the results are summarized in Table 8.1 below.

Table 8.1 Summary of Remediation Target Concentrations for Soil and Groundwater

Run	Aromatic C16 - C21		Aliphatic C12 - C16		Aliphatic C16 - C21	
	Target Concentration		Target Concentration		Target Concentration	
	Level 3 Soil mg/kg	Level 3 Groundwater mg/l	Level 3 Soil mg/kg	Level 3 Groundwater mg/l	Level 3 Soil mg/kg	Level 3 Groundwater mg/l
Run A	1.68E+01	8.85E-03	6.40E+03	8.85E-03	6.85E+05	8.85E-03
Run B	6.84E+00	8.85E-03	2.60E+03	8.85E-03	2.78E+05	8.85E-03
Run C	3.37E+01	8.85E-03	1.28E+04	8.85E-03	1.37E+06	8.85E-03
Run D	1.32E+01	8.85E-03	5.01E+03	8.85E-03	5.36E+05	8.85E-03
Run E	3.11E+00	8.85E-03	-	-	-	-
Run F	1.85E+01	8.85E-03	-	-	-	-
Run G	2.85E+01	1.62E-02	-	-	-	-
Run H	8.16E+01	1.62E-02	-	-	-	-
Run I	1.39E+03	1.94E-01	-	-	-	-
Run J	1.45E+06	1.83E+02	-	-	-	-
Run K	3.39E+01	4.45E-03	1.29E+04	4.45E-03	1.38E+06	4.45E-03
Run L	3.39E+03	4.45E-01	1.29E+06	4.45E-01	1.38E+08	4.45E-01
Run M	9.24E+02	1.21E-01	3.90E+05	1.35E-01	4.18E+07	1.35E-01
Run N	3.39E+01	4.45E-03	-	-	-	-
Run O	1.23E+03	4.45E-01	4.69E+05	4.45E-01	5.01E+07	4.45E-01

The initial runs of the model (Runs A to F) assumed a relatively large source term of 20m by 20m and an infiltration rate representing the site as a whole with 50% hard standing and 50% soft cover. For this initial appraisal the UK Drinking Water Standards were used to derive the target values although it is recognized that this is a stringent approach. Within these runs the effects of varying the hydraulic conductivity, hydraulic gradient, organic matter and infiltration rates were assessed. (see section 8.3 for discussion on sensitivity of the model). Whilst changes to the input parameters resulted in a change in the soils target concentrations the groundwater target concentrations did not vary. Further runs of the model were then undertaken adopting a lower infiltration rate to model conditions in the area of the tank which is covered by hardstanding with an allowance has been made for a proportion of water ingress into the ground through leaking drains and joints in the concrete slab. This lower infiltration rate is considered to be more representative of existing conditions on site and conditions once the site has been redeveloped as this area is and will remain the site entrance covered by hardstanding.

Runs G to J evaluated the effects of a reduction in the size of the source term to 5m by 5m which is considered more representative of the distribution of contamination observed on site in the direction of the groundwater flow. The reduction in the size of the source term increased the target values for both soils and groundwater compared to the earlier runs. Within this second set of analysis consideration was given to time variant models with the assumption that the contamination entered the groundwater sometime between 50 years ago and 20 years ago. A reasonable degree of correlation between the modelled and observed concentrations in the groundwater was obtained for TPH aromatic C16-21 assuming the contamination entered the groundwater around 20 years or so ago.

Run K looked at a 15m compliance point consistent with the distance to the site boundary. For the remaining runs (Run L to O) a 15m compliance point was adopted and consideration given to varying the target concentration. Run L included a target concentration for total TPH in water of 1mg/l which is higher than the drinking water standard but is a reasonably achievable level of remediation of groundwater. Run M considered target concentrations based on the WHO criteria of for the aliphatic fractions of 0.3mg/l and 0.09mg/l for the aromatic fractions considered. Consequently, the calculated target concentrations for remediation in groundwater varied in line with changes in the adopted overall target.

Run N considered the effects of introducing a decay term for the hydrocarbons to model natural decay over time in some of the hydrocarbon fractions. A 3650 day half-life (literature based) made no appreciable difference to the calculated remediation targets as the carbon bands present are ‘heavy’, have relatively low solubility and mobility within the groundwater environment and are thought to represent residual contamination. No allowance for decay of hydrocarbons was included in any other assessments.

Run O assessed the influence of organic matter on the calculated target values. A small decrease in organic matter content made a significant difference to the reported target concentrations for both soils and groundwater.

8.3 Sensitivity Assessment

To assess the sensitivity of the model and the influence of individual parameters, sensitivity analysis has been carried out. The analysis involves varying parameters and observing the effects on the calculated targets. As the hydrocarbon fractions present have relatively low mobility the model was sensitive, for the target values in soils, to changes in hydraulic gradient, hydraulic conductivity, and soil organic matter. The calculated groundwater targets were sensitive to changes to the environmental standard adopted, the assessed size of the source, the distance to the compliance point and the time since the contamination occurred.

8.4 Assessment of Remedial Targets

The analysis has derived remedial targets for both the soils and the groundwater. Almost all of the runs of the model indicate that there is a need for removal of some of the impacted soils from WS4 due to the reported concentration of 1100mg/kg TPH Aromatic C16-C21 exceeding the calculated target concentrations. However, none of the runs suggest that there is a need to remediate the soils due to the reported concentrations of the aliphatic hydrocarbons. It is considered appropriate to adopt the calculated target values from Run M as this is reasonably protective and the proposed remediation targets are summarized in Table 8.2 below.

Table 8.2 Proposed Remediation Targets for Soils and Groundwater

Run	Aromatic C16 - C21		Aliphatic C12 - C16		Aliphatic C16 - C21	
	Target Concentration		Target Concentration		Target Concentration	
	Level 3 Soil mg/kg	Level 3 Groundwater µg/l	Level 3 Soil mg/kg	Level 3 Groundwater µg/l	Level 3 Soil mg/kg	Level 3 Groundwater µg/l
Run M	942	121	390000	135	41800000	135

Table 8.3 below summarises the reported hydrocarbons results in soils for the three bands of interest and comparison is made with the relevant remediation targets in Table 8.2 above.

Table 8.3 Summary of Reported Hydrocarbon Concentrations in Soils

Determinand	WS4 1.0-1.1m mg/kg	WS4 1.65-1.85m mg/kg	WS4 2.15-2.2m mg/kg	BHA 3.0m mg/kg	BHA 4.0m mg/kg	BHA 5.0m mg/kg	BHB 3.5m mg/kg	BHB 4.0m mg/kg	BHB 4.5m mg/kg	BHB 6.0m mg/kg	BHC 3.5m mg/kg	BHD 3.5m mg/kg
Aliphatic TPH >C12-C16	190	710	2900	410	880	< 1.0	< 1.0	44	< 1.0	< 1.0	< 1.0	< 1.0
Aliphatic TPH >C16-C21	230	1000	3700	430	1000	< 1.0	< 1.0	33	< 1.0	< 1.0	< 1.0	< 1.0
Aromatic TPH >C16-C21	< 1.0	< 1.0	**1100**	< 1.0	70	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

As seen in Table 8.3 it is only the reported result from WS4 2.15 to 2.2m depth which exceeds the proposed target concentrations. Removal of the soils from WS4 and any other impacted soils which are found to exceed the target values will protect the groundwater and reduce the likelihood of further impact on the groundwater.

Similarly, Table 8.4 below summarises the results of the latest round of groundwater testing and comparison is made with the calculated remediation targets in Table 8.1

Table 8.4 Summary of Groundwater Analysis 29th March 2023

Determinand	BHA µg/l	BHB µg/l	BHC µg/l	BHD µg/l
Aliphatic TPH >C12-C16	< 0.10	**440**	< 0.10	< 0.10
Aliphatic TPH >C16-C21	< 0.10	**1200**	< 0.10	< 0.10
Aromatic TPH >C16-C21	< 0.10	**250**	< 0.10	< 0.10

As discussed in Section 6 the total concentration of hydrocarbons in the groundwater is around 1.6mg/l and is made up of 3 fractions of relatively low mobility. Although the analysis has derived remediation targets for the groundwater these are very low, around 121 to 135µg/l for each of the carbon bands present and would in practice be very difficult and costly to achieve. Previous experience shows that where there is significant impact on the groundwater it is possible to reduce concentrations of total petroleum hydrocarbons to around 1mg/l, currently at the site the level of total petroleum hydrocarbons in the groundwater is around 1.9mg/l. In addition, the contamination found is considered to be residual, is not on going and appears to be as a result of a leaking tank some 20 to 50 years ago.

It is considered that remediation of the groundwater would be difficult and costly and in practical terms might only result in a very small reduction in the concentrations observed.

9. DISCUSSION AND CONCLUSIONS

9.1 The analysis and assessments presented in this report have derived remediation targets for both soils and groundwater at the site in relation to the three hydrocarbon bands currently observed in the groundwater in BHB.

9.2 Outline remediation proposals currently include removal of the below ground fuel tank in the south western corner of the site along with impacted soils around and below the tank, but above the water table, where practical given constraints on site of the proximity of an existing building, Knowle House, and the road. Excavation and removal of granular soils close to and below the water table is not practical. However, the worst of the impacted soils appear to be above the water table and down hydraulic gradient from the tank around WS4 where some of the concentrations in the soils exceed the calculated soil remediation targets. The removal of the impacted soils which exceed the remediation targets will help to reduce any potential further impact on the groundwater.

9.3 As discussed in Section 8.4, whilst the current concentrations of hydrocarbons in BHB exceed the calculated groundwater remediation targets, the calculated targets are very low and are unlikely to be achievable in practice. In addition, the overall total concentration of hydrocarbons in the groundwater is not considered particularly severe. The proposed removal of the more significant impacted soils, where practical, will reduce the likelihood of future impact on the groundwater.

9.4 The observed contamination is historic and the source is not being replenished. The hydrocarbons which are present on site have low overall mobility within the groundwater environment and as such are thought unlikely to pose significant risk.

R. Foord BSc, MSc, MCSM, CGeol, FGS

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3. CL:AIRE (2017). Petroleum Hydrocarbons in Groundwater: Guidance on Assessing Petroleum Hydrocarbons Using Existing Hydrogeological Risk Assessment Methodologies, CL:AIRE, London.

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The report is based on the ground conditions encountered in the exploratory holes together with the results of field and laboratory testing in the context of the proposed development. Conditions between exploratory holes have been interpolated, however soil conditions are highly variable and may differ from the interpolation. There may be conditions, appertaining to the site, which may not be revealed by the investigation, and which may not be taken into account in the report.

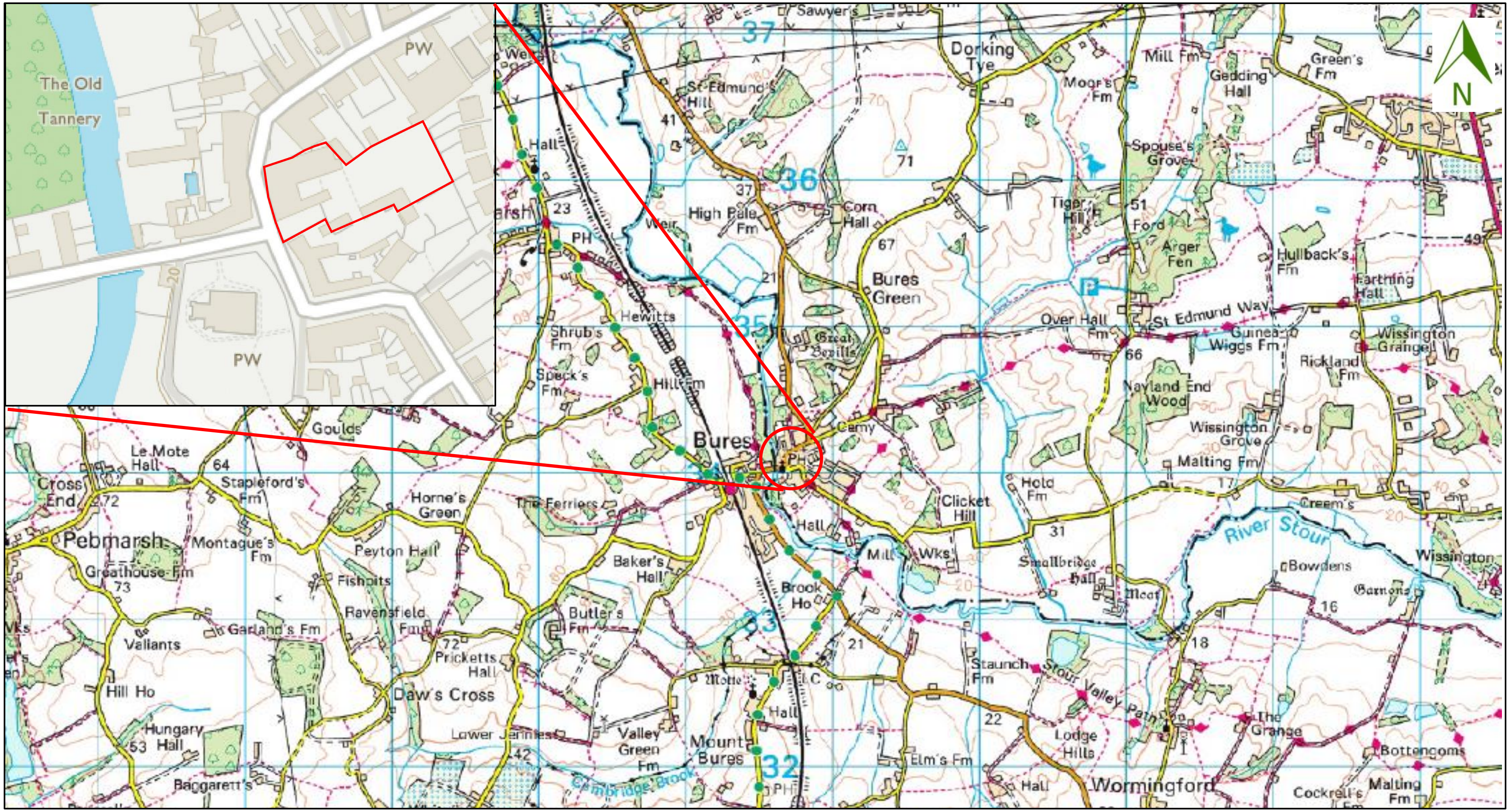
The accuracy of the results reported will depend on the technique of measurement, investigation and test used and these values should not be regarded necessarily as characteristic of the strata as a whole. Where such measurements are critical, the technique of the investigation will need to be reviewed and supplementary investigation undertaken in accordance with the advice of the company where necessary.

The economic viability of the proposal referred to in the report, or of the solutions put forward to any problems encountered, will depend on very many factors in addition to the geotechnical considerations hence its evaluation will be outside the scope of the report.

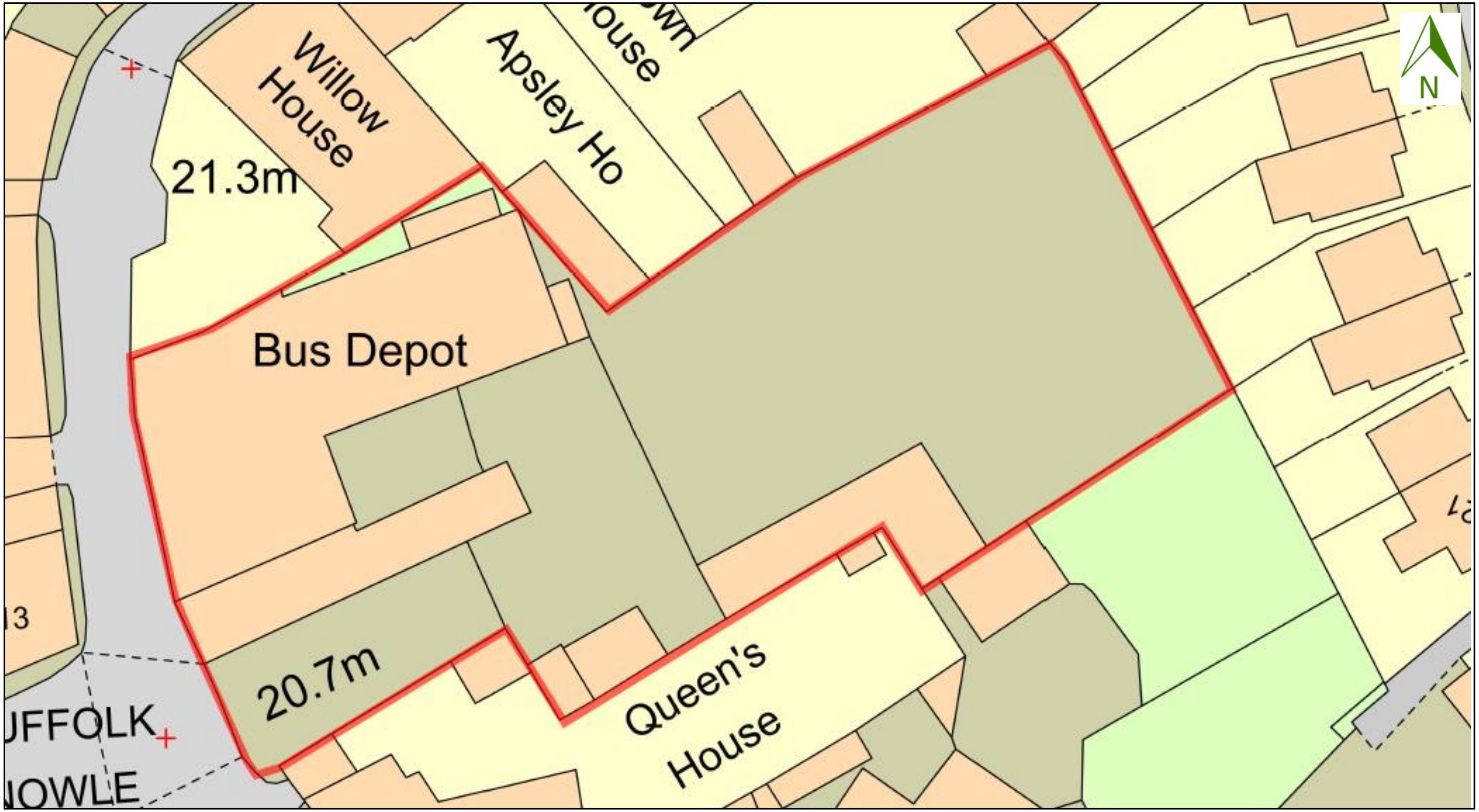
Where any data supplied by the Client or from other sources, including previous site investigations, have been used it has been assumed that the information is correct. No responsibility can be accepted by Compass Geotechnical Limited for inaccuracies in the data supplied by any other party.

The investigation does not include the identification of Japanese Knotweed. Any such survey should be undertaken by a specialist.

Appendix (i)
Figures



Reproduced with the permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationery Office, © Crown Copyright Licence No: AL100034022.	**Figure 1**	Site Location Plan
	Date	April 2023
	Not to Scale	



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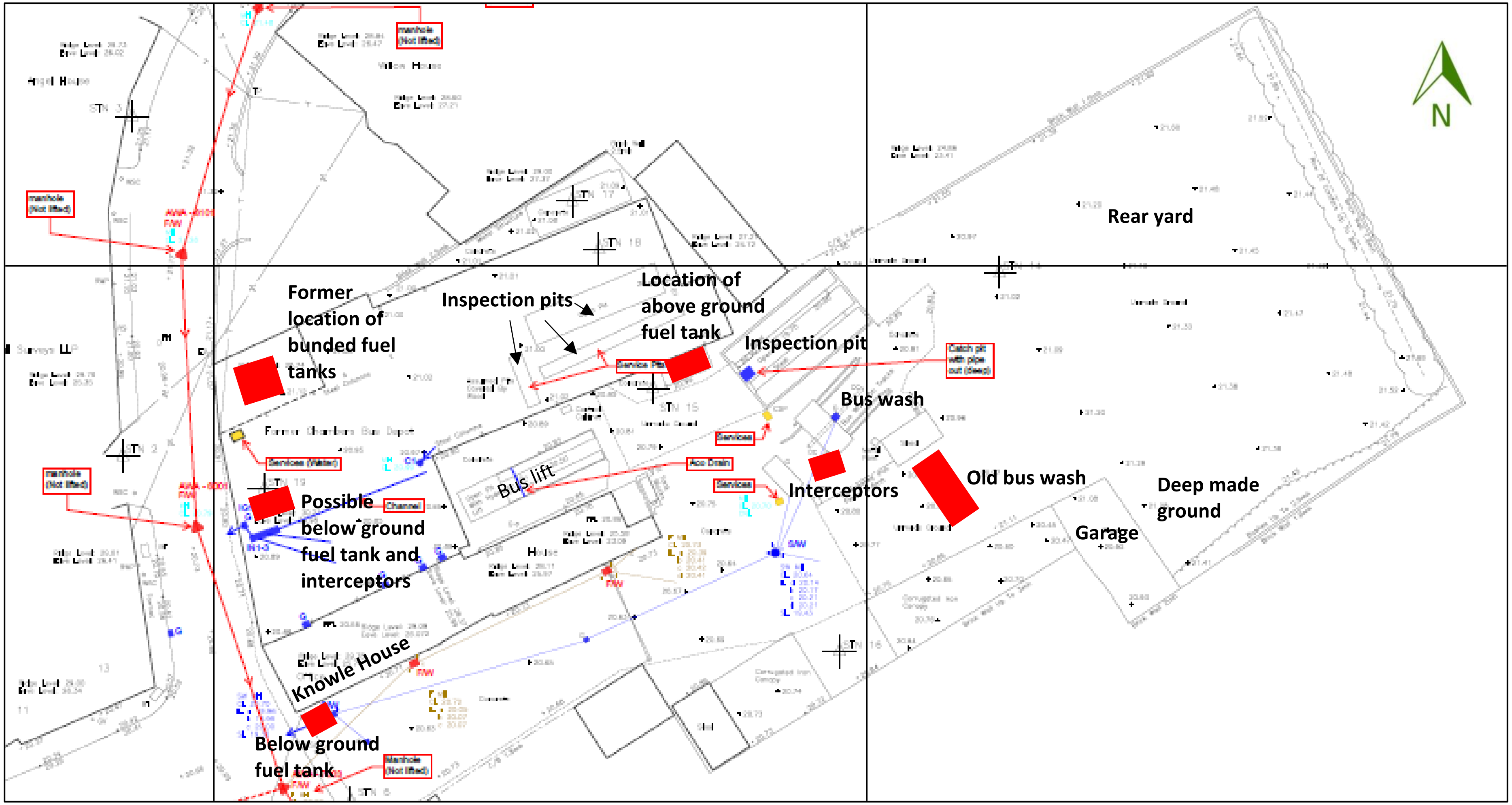
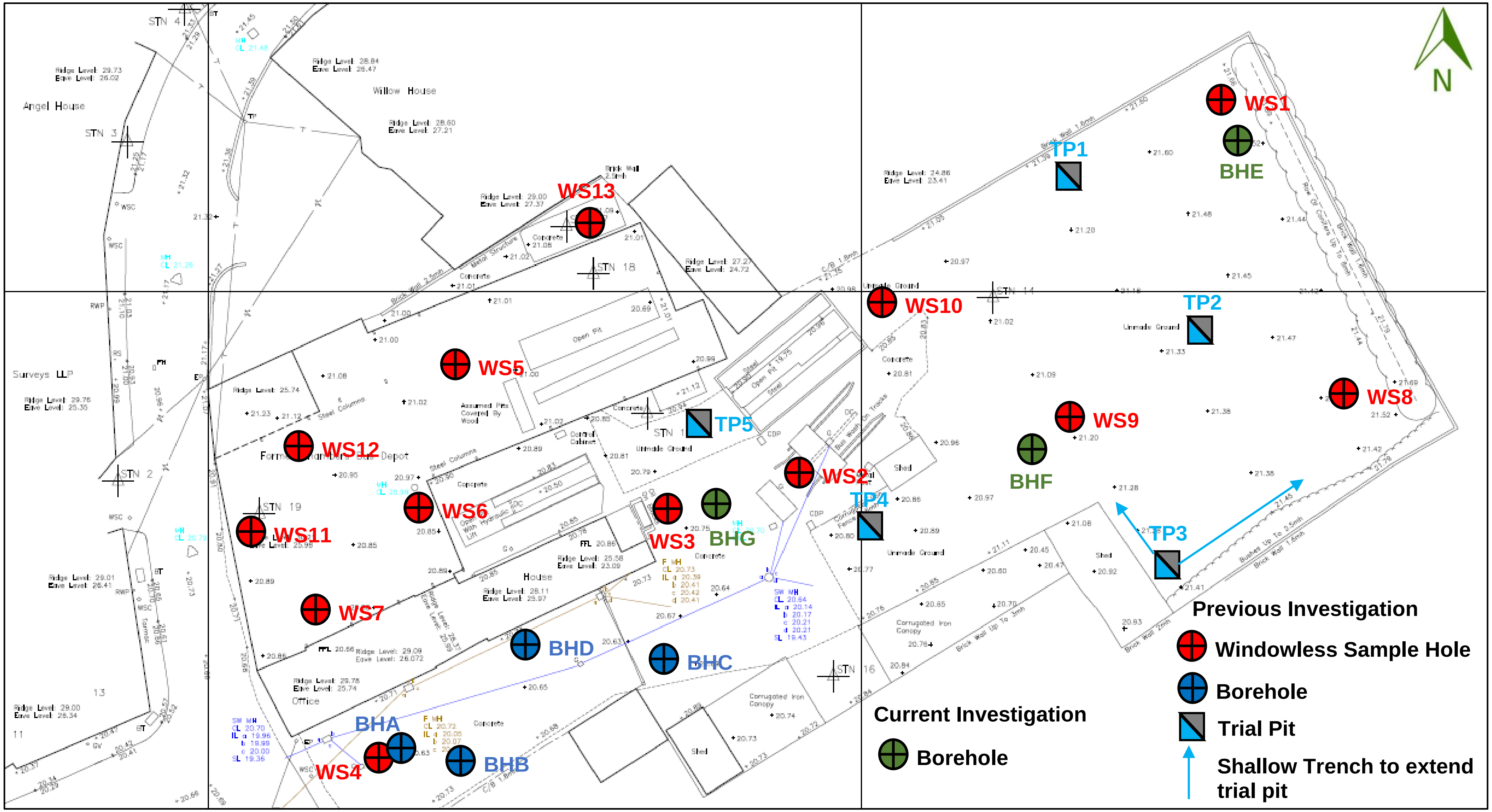
	Date	April 2023
	Not to Scale	

Extract from Rose Builders/Robert R Leeds Drawing No: 2473/6A Revision A dated 04.01.23	**Figure 3**	Proposed Layout Plan
	Date	April 2023
	Not to Scale	



Extract from Randall Surveys Existing Site Layout Drawing No: 16449/OG/1 dated June 2021 with additional drainage	**Figure 4**	Annotated Site Plan
	Date	April 2023
	Not to Scale	



Extract from Randall Surveys Existing Site Layout Drawing No: 16449/OG/1 dated June 2021	**Figure 5**	Exploratory Hole Plan
	Date	April 2023
	Not to Scale	

Appendix (ii)
Groundwater Monitoring Results and Plots

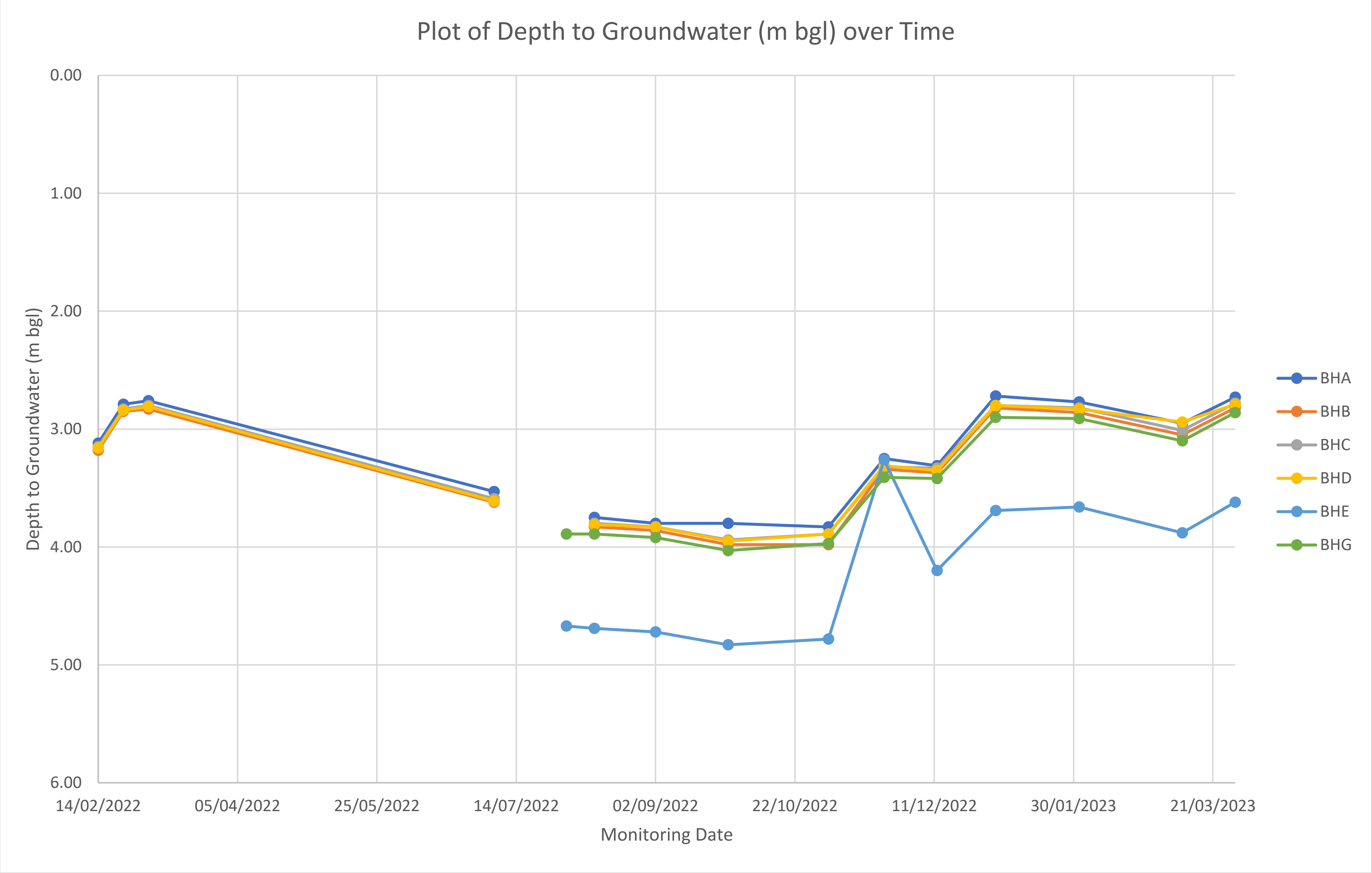
Groundwater Monitoring

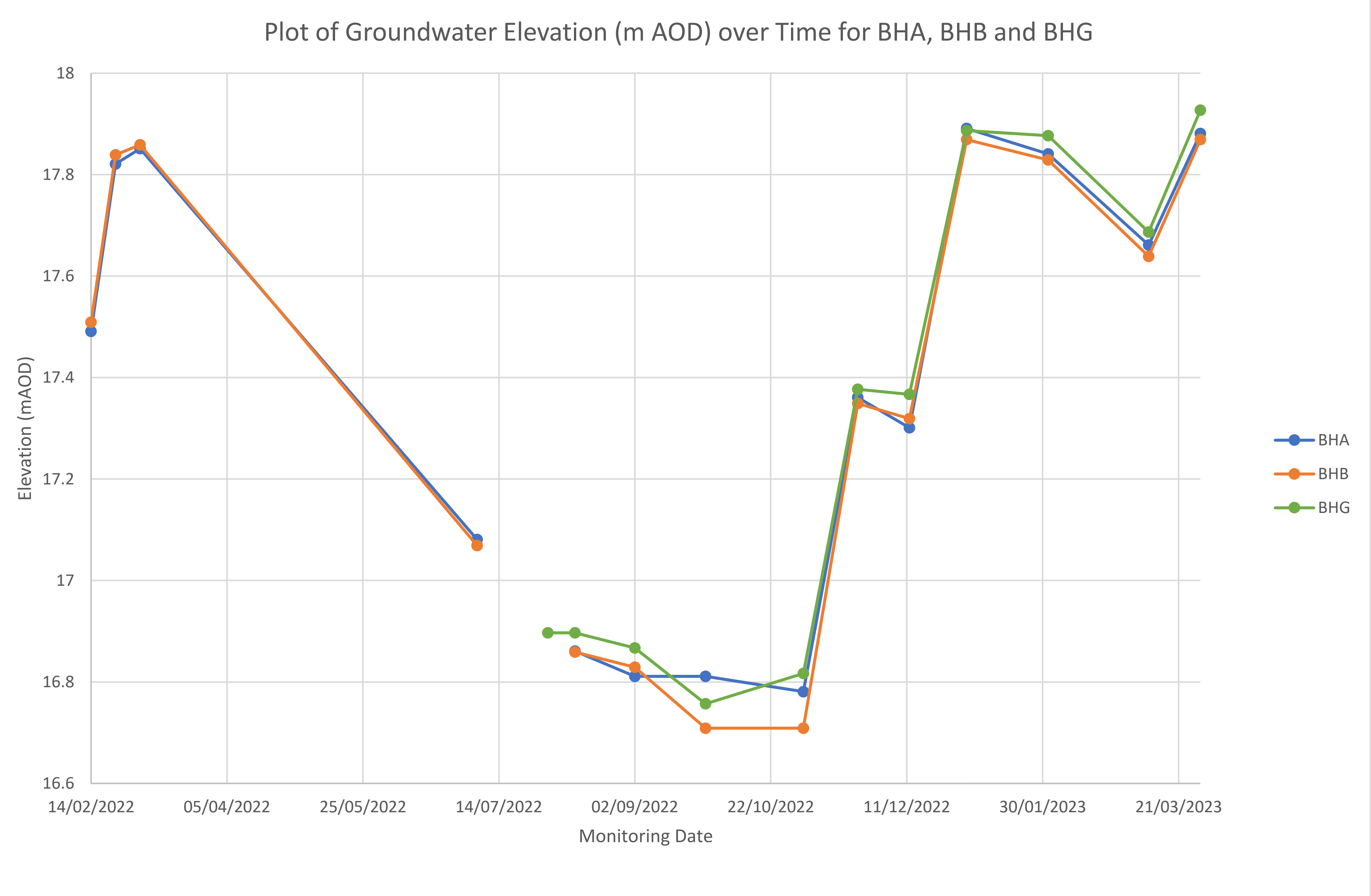
SITE	**Former Chambers Bus Garage, Bures**

Date	Position	Depth to Water (m bgl)	Total Depth (m bgl)	Groundwater Elevation (mAOD)	Comments
14.02.22	BHA	3.12	5.47	17.491	
	BHB	3.18	5.87	17.509	
	BHC	3.15	5.79	17.544	
	BHD	3.16	5.90	17.504	
	WS2	3.27	3.49	17.554	
23.02.22	BHA	2.79	5.47	17.821	
	BHB	2.85	5.84	17.839	
	BHC	2.83	5.78	17.864	
	BHD	2.84	5.90	17.824	
04.03.22	BHA	2.76	5.50	17.851	
	BHB	2.83	5.74	17.859	
	BHC	2.80	5.71	17.894	
	BHD	2.81	5.89	17.854	
	WS2	2.91	3.48	17.914	
06.07.22	BHA	3.53	5.56	17.081	
	BHB	3.62	5.81	17.069	
	BHC	3.59	5.76	17.104	
	BHD	3.61	5.96	17.054	
	WS2	-	3.54		40mm silt in base
01.08.22	BHE	4.67	6.44	16.879	
	BHG	3.89	6.95	16.897	
11.08.22	BHA	3.75	5.47	16.861	slight odour
	BHB	3.83	5.71	16.859	very slight odour
	BHC	3.80	5.69	16.894	
	BHD	3.81	5.88	16.854	
	BHE	4.69	6.38	16.859	
	BHG	3.89	6.83	16.897	

Date	Position	Depth to Water (m bgl)	Total Depth (m bgl)	Groundwater Elevation (mAOD)	Comments
02.09.22	BHA	3.80	5.50	16.811	Slight odour
	BHB	3.86	5.72	16.829	very slight odour
	BHC	3.83	5.69	16.864	
	BHD	3.83	5.89	16.834	
	BHE	4.72	6.38	16.829	
	BHG	3.92	6.84	16.867	
	WS2	dry	3.45		
28.09.22	BHA	3.80	5.48	16.811	Slight odour
	BHB	3.98	5.73	16.709	very slight odour
	BHC	3.94	5.69	16.754	
	BHD	3.95	5.89	16.714	
	BHE	4.83	6.36	16.719	
	BHG	4.03	6.84	16.757	
	WS2	dry	3.45		
03.11.22	BHA	3.83	5.49	16.781	Slight odour
	BHB	3.98	5.78	16.709	very slight odour
	BHC	3.89	5.70	16.804	
	BHD	3.89	5.88	16.774	
	BHE	4.78	6.34	16.769	
	BHG	3.97	6.83	16.817	
	WS2	dry	3.45		
23.11.22	BHA	3.25	5.49	17.361	Slight odour
	BHB	3.34	5.72	17.349	very slight odour
	BHC	3.32	5.70	17.374	
	BHD	3.31	5.89	17.354	
	BHE	3.26	6.27	18.289	
	BHG	3.41	6.82	17.377	
	WS2	3.45	3.45		
12.12.22	BHA	3.31	5.49	17.301	Slight odour
	BHB	3.37	5.73	17.319	very slight odour
	BHC	3.33	5.70	17.364	
	BHD	3.35	5.89	17.314	
	BHE	4.20	6.26	17.349	
	BHG	3.42	6.82	17.367	
	WS2	3.45	3.46	17.374	

Date	Position	Depth to Water (m bgl)	Total Depth (m bgl)	Groundwater Elevation (mAOD)	Comments
02.01.23	BHA	2.72	5.47	17.891	Very slight odour
	BHB	2.82	5.72	17.869	Slight odour
	BHC	2.80	5.69	17.894	
	BHD	2.80	5.88	17.864	
	BHE	3.69	6.21	17.859	
	BHG	2.90	6.82	17.887	
	WS2	2.92	3.46	17.744	
01.02.23	BHA	2.77	5.46	17.841	
	BHB	2.86	5.72	17.829	
	BHC	2.82	5.70	17.874	
	BHD	2.83	5.89	17.834	
	BHE	3.66	6.31	17.889	
	BHG	2.91	6.83	17.877	
	WS2	2.93	3.47	17.734	
10.03.23	BHA	2.95	5.49	17.661	
	BHB	3.05	5.72	17.639	
	BHC	3.01	5.70	17.684	
	BHD	2.94	5.88	17.724	
	BHE	3.88	6.31	17.669	
	BHG	3.10	6.83	17.687	
	WS2	3.13	3.45	17.534	
29.03.23	BHA	2.73	5.49	17.881	
	BHB	2.82	5.71	17.869	
	BHC	2.78	5.70	17.914	
	BHD	2.79	5.89	17.874	
	BHE	3.62	6.31	17.929	
	BHG	2.86	6.89	17.927	
	WS2	2.88	3.46	17.784	


Plot of Depth to Groundwater (m bgl) over Time
Depth to Groundwater (m bgl)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
14/02/2022
05/04/2022
25/05/2022
14/07/2022
02/09/2022
22/10/2022
11/12/2022
30/01/2023
21/03/2023
Monitoring Date
BHA
BHB
BHC
BHD
BHE
BHG


Plot of Groundwater Elevation (m AOD) over Time for BHA, BHB and BHG
Elevation (mAOD)
18
17.8
17.6
17.4
17.2
17
16.8
16.6
14/02/2022
05/04/2022
25/05/2022
14/07/2022
02/09/2022
22/10/2022
11/12/2022
30/01/2023
21/03/2023
Monitoring Date
BHA
BHB
BHG

Appendix (iii)
Permeability Test Results

Variable Head Permeability Test in a Borehole - Field Data

SITE	**Former Chambers Bus Garage, Bures**		
Position	**BHE**	**Date**	**29.03.23**

Test 1	29.03.23	**Test 2**		**Test 3**	
Depth to Water Before filling (m)	3.62	**Depth to Water Before filling (m)**		**Depth to Water Before filling (m)**	
Elapsed Time (Minutes)	**Depth to Water (m)**	**Elapsed Time (Minutes)**	**Depth to Water (m)**	**Elapsed Time (Mintues)**	**Depth to Water (m)**
0	0.00	0		0	
0.03	3.62	1		1	
Water drained away to full depth in less than 5 seconds		2		2	
		3		3	
		4		4	
		5		5	
		7		7	
		10		10	
		15		15	
		20		20	
		25		25	
		30		30	
		40		40	
		50		50	
		60		60	
		75		75	
		90		90	
		120		120	
		150		150	
		180		180	
		210		210	
		240		240	
		300		300	
		360		360	
		420		420	
		480		480	
Depth to Water at end of test (m)	3.62	**Depth to Water at end of test (m)**		**Depth to Water at end of test (m)**	

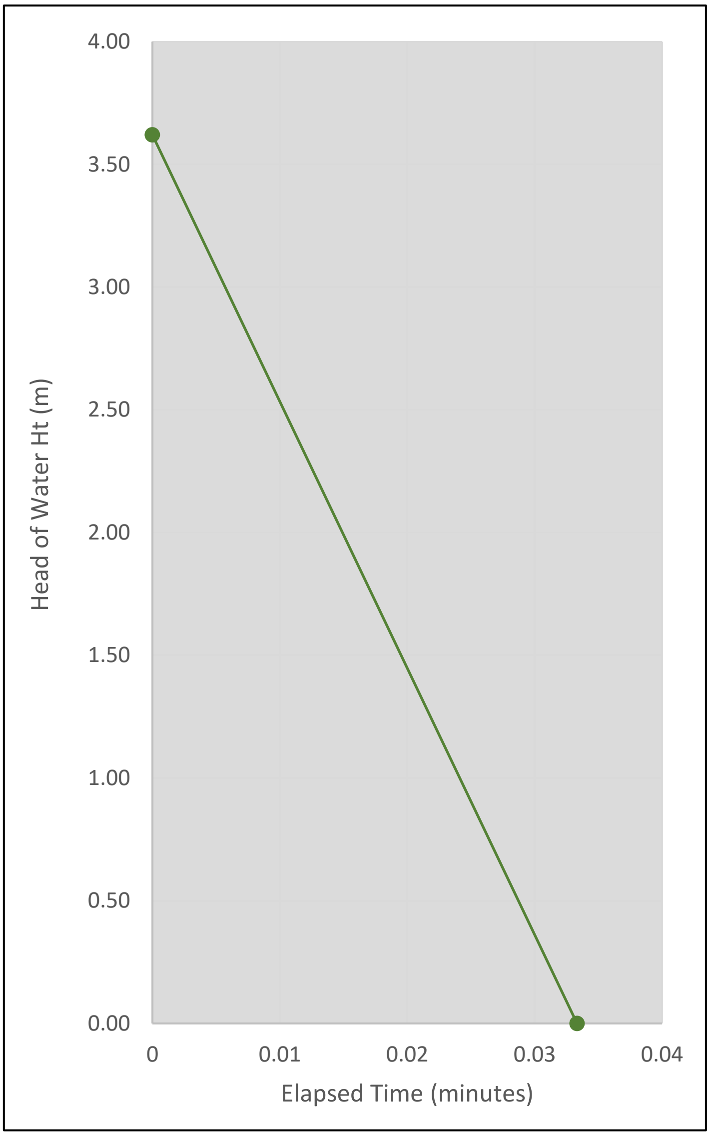
Compass Geotechnical Ltd
Geotechnical, Geoenvironmental and Civil Engineering Consultants

Variable Head Permeability Test in a Borehole
(BS EN ISO 22282-1:2012 and BS EN ISO 22282-2:2012)

SITE	**Former Chambers Bus Garage, Bures**		
Position	**BHE Test 1**	**Date**	29.03.23

Total Depth of Borehole (m)	6.31	**Initial Head of Water (H_0)**	3.62
Borehole Diameter (m)	0.15	**Final Head of Water (H_1)**	0.00
Response Zone Top (m)	1.00	**Time T0 at H0 (seconds)**	0
Response Zone Bottom (m)	6.31	**Time T1 at H1 (seconds)**	2
Diameter of Pipe (m)	0.05	**Cross Section Area S (m^2)**	0.00196
Standing Water Level (m)	3.62	**Response Zone Length (m)**	5.31

Elapsed Time (minutes)	Depth to Water (m)	Head of Water H_t (m)
0	0.00	3.62
0.03	3.62	0.00



Shape Factor F (BS EN ISO 22282:1-2012)	7.83	**Borehole Permeability k (m/s)** $K=\frac{SLN(\frac{H0}{H1})}{F(T1-T0)}$	**1.60E-03**

Variable Head Permeability Test in a Borehole - Field Data

SITE	**Former Chambers Bus Garage, Bures**		
Position	**BHG**	**Date**	**29.03.23**

Test 1	29.03.23	**Test 2**		**Test 3**	
Depth to Water Before filling (m)	2.86	**Depth to Water Before filling (m)**		**Depth to Water Before filling (m)**	
Elapsed Time (Minutes)	**Depth to Water (m)**	**Elapsed Time (Minutes)**	**Depth to Water (m)**	**Elapsed Time (Mintues)**	**Depth to Water (m)**
0	0.00	0		0	
0.08	2.86	1		1	
Water drained away to full depth in less than 5 seconds		2		2	
		3		3	
		4		4	
		5		5	
		7		7	
		10		10	
		15		15	
		20		20	
		25		25	
		30		30	
		40		40	
		50		50	
		60		60	
		75		75	
		90		90	
		120		120	
		150		150	
		180		180	
		210		210	
		240		240	
		300		300	
		360		360	
		420		420	
		480		480	
Depth to Water at end of test (m)	2.86	**Depth to Water at end of test (m)**		**Depth to Water at end of test (m)**	

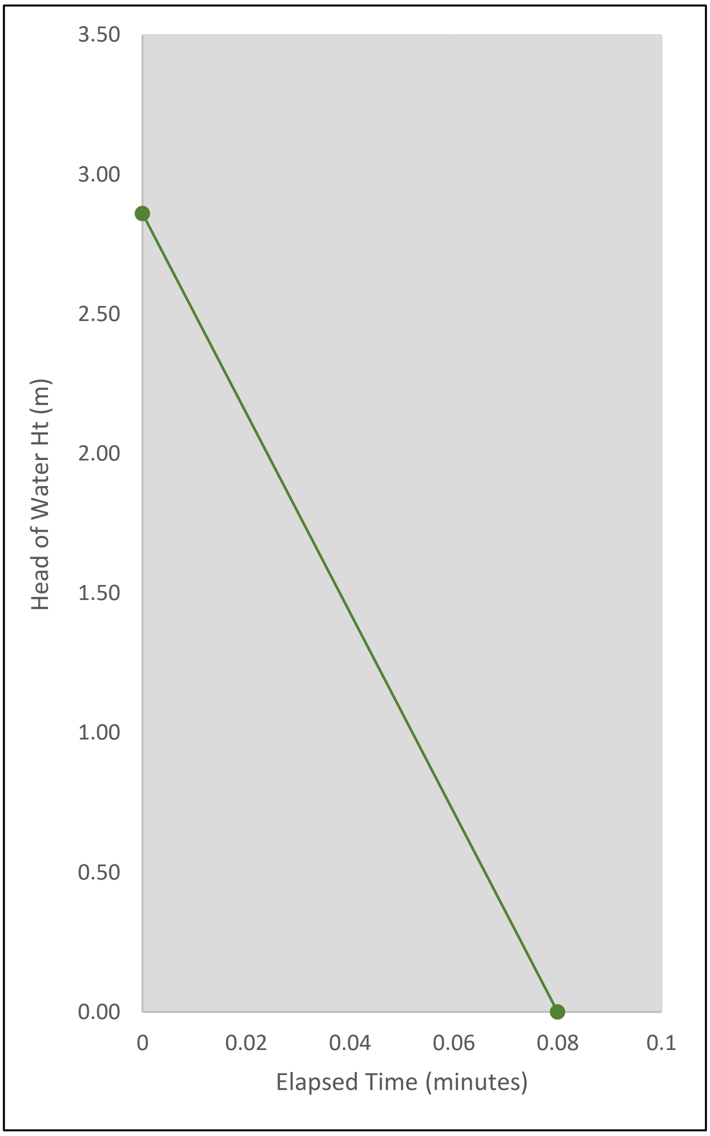
Variable Head Permeability Test in a Borehole

(BS EN ISO 22282-1:2012 and BS EN ISO 22282-2:2012)

SITE	**Former Chambers Bus Garage, Bures**		
Position	**BHG Test 1**	**Date**	29.03.23

Total Depth of Borehole (m)	6.89	**Initial Head of Water (H_0)**	2.86
Borehole Diameter (m)	0.15	**Final Head of Water (H_1)**	0.00
Response Zone Top (m)	1.00	**Time T0 at H0 (seconds)**	0
Response Zone Bottom (m)	6.89	**Time T1 at H1 (seconds)**	4.8
Diameter of Pipe (m)	0.05	**Cross Section Area S (m^2)**	0.00196
Standing Water Level (m)	2.86	**Response Zone Length (m)**	5.89

Elapsed Time (minutes)	Depth to Water (m)	Head of Water H_t (m)
0	0.00	2.86
0.08	2.86	0.00



Shape Factor F (BS EN ISO 22282:1-2012)	8.48	**Borehole Permeability k (m/s)** $K=\frac{SLN(\frac{H0}{H1})}{F(T1-T0)}$	**6.06E-04**

Appendix (iv)
Laboratory Test Results - Groundwater

Eurofins Chemtest Ltd
Depot Road
Newmarket
CB8 0AL
Tel: 01638 606070
Email: info@chemtest.com

Final Report

Report No.:	23-10679-1		
Initial Date of Issue:	11-Apr-2023		
Client	Compass Geotechnical Limited		
Client Address:	13 Willow Park, Upton Lane Stoke Golding Warwickshire CV13 6EU		
Contact(s):	rachel@compassgeotechnical.co.uk		
Project	Bures		
Quotation No.:	Q19-18078	**Date Received:**	31-Mar-2023
Order No.:	222945 W	**Date Instructed:**	31-Mar-2023
No. of Samples:	4		
Turnaround (Wkdays):	5	**Results Due:**	06-Apr-2023
Date Approved:	11-Apr-2023		
Approved By:			
Details:	Stuart Henderson, Technical Manager		

Results - Water

Project: Bures

Client: Compass Geotechnical Limited				**Chemtest Job No.:**	23-10679	23-10679	23-10679	23-10679
Quotation No.: Q19-18078				**Chemtest Sample ID.:**	1616344	1616345	1616346	1616347
				Client Sample ID.:	W	W	W	W
				Sample Location:	BHA	BHB	BHC	BHD
				Sample Type:	WATER	WATER	WATER	WATER
				Top Depth (m):	2.9	3.0	3.0	3.0
				Date Sampled:	29-Mar-2023	29-Mar-2023	29-Mar-2023	29-Mar-2023
				Time Sampled:	0:00	0:00	0:00	0:00
Determinand	**Accred.**	**SOP**	**Units**	**LOD**				
Aliphatic TPH >C5-C6	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C6-C8	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C8-C10	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C10-C12	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C12-C16	N	1675	µg/l	0.10	< 0.10	440	< 0.10	< 0.10
Aliphatic TPH >C16-C21	N	1675	µg/l	0.10	< 0.10	1200	< 0.10	< 0.10
Aliphatic TPH >C21-C35	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aliphatic TPH >C35-C44	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Total Aliphatic Hydrocarbons	N	1675	µg/l	5.0	< 5.0	1700	< 5.0	< 5.0
Aromatic TPH >C5-C7	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C7-C8	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C8-C10	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C10-C12	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C12-C16	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C16-C21	N	1675	µg/l	0.10	< 0.10	250	< 0.10	< 0.10
Aromatic TPH >C21-C35	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Aromatic TPH >C35-C44	N	1675	µg/l	0.10	< 0.10	< 0.10	< 0.10	< 0.10
Total Aromatic Hydrocarbons	N	1675	µg/l	5.0	< 5.0	250	< 5.0	< 5.0
Total Petroleum Hydrocarbons	N	1675	µg/l	10	< 10	1900	< 10	< 10
Benzene	U	1760	µg/l	1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	U	1760	µg/l	1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	U	1760	µg/l	1.0	< 1.0	< 1.0	< 1.0	< 1.0
m & p-Xylene	U	1760	µg/l	1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	U	1760	µg/l	1.0	< 1.0	< 1.0	< 1.0	< 1.0
Methyl Tert-Butyl Ether	N	1760	µg/l	1.0	< 1.0	< 1.0	< 1.0	< 1.0
N-Nitrosodimethylamine	N	1790	µg/l	0.50	< 0.50	< 0.50		
Phenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Chlorophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
Bis-(2-Chloroethyl)Ether	N	1790	µg/l	0.50	< 0.50	< 0.50		
1,3-Dichlorobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
1,4-Dichlorobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
1,2-Dichlorobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Methylphenol (o-Cresol)	N	1790	µg/l	0.50	< 0.50	< 0.50		
Bis(2-Chloroisopropyl)Ether	N	1790	µg/l	0.50	< 0.50	< 0.50		
Hexachloroethane	N	1790	µg/l	0.50	< 0.50	< 0.50		
N-Nitrosodi-n-propylamine	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Methylphenol	N	1790	µg/l	0.50	< 0.50	< 0.50		

Results - Water

Project: Bures

Client: Compass Geotechnical Limited	**Chemtest Job No.:**				23-10679	23-10679	23-10679	23-10679
Quotation No.: Q19-18078	**Chemtest Sample ID.:**				1616344	1616345	1616346	1616347
	Client Sample ID.:				W	W	W	W
	Sample Location:				BHA	BHB	BHC	BHD
	Sample Type:				WATER	WATER	WATER	WATER
	Top Depth (m):				2.9	3.0	3.0	3.0
	Date Sampled:				29-Mar-2023	29-Mar-2023	29-Mar-2023	29-Mar-2023
	Time Sampled:				0:00	0:00	0:00	0:00
Determinand	**Accred.**	**SOP**	**Units**	**LOD**				
Nitrobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Isophorone	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Nitrophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
2,4-Dimethylphenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
Bis(2-Chloroethoxy)Methane	N	1790	µg/l	0.50	< 0.50	< 0.50		
2,4-Dichlorophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
1,2,4-Trichlorobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Naphthalene	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Chloroaniline	N	1790	µg/l	0.50	< 0.50	< 0.50		
Hexachlorobutadiene	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Chloro-3-Methylphenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Methylnaphthalene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Hexachlorocyclopentadiene	N	1790	µg/l	0.50	< 0.50	< 0.50		
2,4,6-Trichlorophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
2,4,5-Trichlorophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Chloronaphthalene	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Nitroaniline	N	1790	µg/l	0.50	< 0.50	< 0.50		
Acenaphthylene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Dimethylphthalate	N	1790	µg/l	0.50	< 0.50	< 0.50		
2,6-Dinitrotoluene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Acenaphthene	N	1790	µg/l	0.50	< 0.50	< 0.50		
3-Nitroaniline	N	1790	µg/l	0.50	< 0.50	< 0.50		
Dibenzofuran	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Chlorophenylphenylether	N	1790	µg/l	0.50	< 0.50	< 0.50		
2,4-Dinitrotoluene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Fluorene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Diethyl Phthalate	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Nitroaniline	N	1790	µg/l	0.50	< 0.50	< 0.50		
2-Methyl-4,6-Dinitrophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
Azobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Bromophenylphenyl Ether	N	1790	µg/l	0.50	< 0.50	< 0.50		
Hexachlorobenzene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Pentachlorophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		
Phenanthrene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Anthracene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Carbazole	N	1790	µg/l	0.50	< 0.50	< 0.50		
Di-N-Butyl Phthalate	N	1790	µg/l	0.50	< 0.50	< 0.50		

Results - Water

Project: Bures

Client: Compass Geotechnical Limited				**Chemtest Job No.:**	23-10679	23-10679	23-10679	23-10679
Quotation No.: Q19-18078				**Chemtest Sample ID.:**	1616344	1616345	1616346	1616347
				Client Sample ID.:	W	W	W	W
				Sample Location:	BHA	BHB	BHC	BHD
				Sample Type:	WATER	WATER	WATER	WATER
				Top Depth (m):	2.9	3.0	3.0	3.0
				Date Sampled:	29-Mar-2023	29-Mar-2023	29-Mar-2023	29-Mar-2023
				Time Sampled:	0:00	0:00	0:00	0:00
Determinand	**Accred.**	**SOP**	**Units**	**LOD**				
Fluoranthene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Pyrene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Butylbenzyl Phthalate	N	1790	µg/l	0.50	< 0.50	< 0.50		
Benzo[a]anthracene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Chrysene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Bis(2-Ethylhexyl)Phthalate	N	1790	µg/l	0.50	< 0.50	< 0.50		
Di-N-Octyl Phthalate	N	1790	µg/l	0.50	< 0.50	< 0.50		
Benzo[b]fluoranthene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Benzo[k]fluoranthene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Benzo[a]pyrene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Indeno(1,2,3-c,d)Pyrene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Dibenz(a,h)Anthracene	N	1790	µg/l	0.50	< 0.50	< 0.50		
Benzo[g,h,i]perylene	N	1790	µg/l	0.50	< 0.50	< 0.50		
4-Nitrophenol	N	1790	µg/l	0.50	< 0.50	< 0.50		

Test Methods

SOP	Title	Parameters included	Method summary
1675	TPH Aliphatic/Aromatic split in Waters by GC-FID(cf. Texas Method 1006 / TPH CWG)	Aliphatics: >C5–C6, >C6–C8, >C8– C10, >C10–C12, >C12–C16, >C16–C21, >C21–C35, >C35– C44Aromatics: >C5–C7, >C7–C8, >C8– C10, >C10–C12, >C12–C16, >C16– C21, >C21– C35, >C35– C44	Pentane extraction / GCxGC FID detection
1760	Volatile Organic Compounds (VOCs) in Waters by Headspace GC-MS	Volatile organic compounds, including BTEX and halogenated Aliphatic/Aromatics. (cf. USEPA Method 8260)	Automated headspace gas chromatographic (GC) analysis of water samples with mass spectrometric (MS) detection of volatile organic compounds.
1790	Semi-Volatile Organic Compounds (SVOCs) in Waters by GC-MS	Semi-volatile organic compounds	Solvent extraction / GCMS detection

Report Information

Key	
U	UKAS accredited
M	MCERTS and UKAS accredited
N	Unaccredited
S	This analysis has been subcontracted to a UKAS accredited laboratory that is accredited for this analysis
SN	This analysis has been subcontracted to a UKAS accredited laboratory that is not accredited for this analysis
T	This analysis has been subcontracted to an unaccredited laboratory
I/S	Insufficient Sample
U/S	Unsuitable Sample
N/E	not evaluated
<	"less than"
>	"greater than"
SOP	Standard operating procedure
LOD	Limit of detection

Comments or interpretations are beyond the scope of UKAS accreditation

The results relate only to the items tested

Uncertainty of measurement for the determinands tested are available upon request

None of the results in this report have been recovery corrected

All results are expressed on a dry weight basis

The following tests were analysed on samples as received and the results subsequently corrected to a dry weight basis TPH, BTEX, VOCs, SVOCs, PCBs, Phenols

For all other tests the samples were dried at < 37°C prior to analysis

All Asbestos testing is performed at the indicated laboratory

Issue numbers are sequential starting with 1 all subsequent reports are incremented by 1

Sample Deviation Codes

A - Date of sampling not supplied
B - Sample age exceeds stability time (sampling to extraction)
C - Sample not received in appropriate containers
D - Broken Container
E - Insufficient Sample (Applies to LOI in Trommel Fines Only)

Sample Retention and Disposal

All soil samples will be retained for a period of 30 days from the date of receipt

All water samples will be retained for 14 days from the date of receipt

Charges may apply to extended sample storage

If you require extended retention of samples, please email your requirements to:
customerservices@chemtest.com

Appendix (v)
RTM Calculations

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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**19-Apr-23**		**Version:**	**Run A**
Contaminant	**Aro C16 - C21**			
Target Concentration (C_T)	**0.0033**	**mg/l**	**Origin of C_T:**	**Uk Drinking Water Standard**

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 comparision 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

Environment Agency

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		**Aro C16 - C21**	
Target concentration	**C_T**	**0.0033**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	1.30E-02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	[redacted]	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$	[redacted]	l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg	
pH value	pH	[redacted]	pH units	
Acid dissociation constant	pKa	[redacted]		
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**9.01E+01**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**2.98E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0033	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	19-Apr-23
Version:	Run A

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16 - C21**		from Level 1	This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).
Target concentration	**C_T**	**0.0033**	**mg/l**	from Level 1	

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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.03E-03	m/d	**Met Office rainfall data 50% hardstanding drains**	
Area of contaminant source	A	4.19E+02	m^2	**Estimated from site observations 20x20m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	2.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	1.00E+01	m	**Estimated from site width of yard**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	2.20E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.75E+01**		
Level 2 Remedial Target		**9.08E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		8.19E+00	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	19-Apr-23
Version:	Run A

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aro C16 - C21		from Level 1
Target Concentration	C_T	0.0033	mg/l	from Level 1
Dilution Factor	DF	2.75E+01		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	**Soil concentration as mg/kg**			
Enter soil concentration		1100	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	1.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	2.20E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.87E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	4.00E+01	m	*Assessed*
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	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	4.000	m	*see options*
Transverse dispersivity	az	0.400	m	*see options*
Vertical dispersivity	ay	0.040	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.72E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	4.99E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.87E-03	fraction
Rate of contaminant flow due to retardation	u	1.24E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	4.87E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**2.05E+00**	**fraction**
Calculated soil leachate concentration	Co	1.22E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**1.87E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.68E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**40**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**4.87E-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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

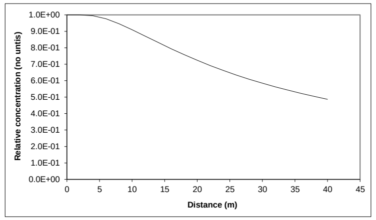
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	4.00E+00	2.59E+00	m
Transverse dispersivity	**az**	0.00E+00	4.00E-01	2.59E-01	m
Vertical dispersivity	**ay**	0.00E+00	4.00E-02	2.59E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run A

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	4.43E-01
2.0	1.00E+00	4.43E-01
4.0	9.95E-01	4.41E-01
6.0	9.76E-01	4.33E-01
8.0	9.46E-01	4.19E-01
10.0	9.10E-01	4.03E-01
12.0	8.71E-01	3.86E-01
14.0	8.32E-01	3.69E-01
16.0	7.94E-01	3.52E-01
18.0	7.58E-01	3.36E-01
20.0	7.24E-01	3.21E-01
22.0	6.92E-01	3.07E-01
24.0	6.62E-01	2.93E-01
26.0	6.35E-01	2.81E-01
28.0	6.09E-01	2.70E-01
30.0	5.85E-01	2.59E-01
32.0	5.62E-01	2.49E-01
34.0	5.42E-01	2.40E-01
36.0	5.22E-01	2.31E-01
38.0	5.04E-01	2.23E-01
40.0	4.87E-01	2.16E-01

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	1.00E+00	mg/kg

Level 1 Parameters

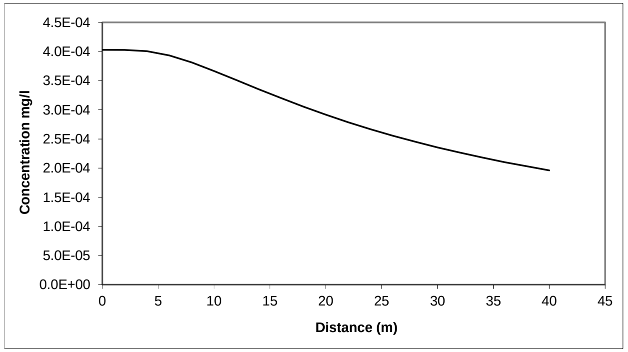
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.01E+01	l/kg
Factor (partitioning between soil and water)		9.02E+01	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	2.75E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	2.05E+00

Predicted concentrations at compliance point

Level 1	C	1.11E-02	mg/l	No dilution or attenuation
Level 2	C	4.03E-04	mg/l	Dilution taken into account
Level 3	C	1.96E-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	4.03E-04
2.00	4.03E-04
4.00	4.01E-04
6.00	3.93E-04
8.00	3.81E-04
10.00	3.67E-04
12.00	3.51E-04
14.00	3.35E-04
16.00	3.20E-04
18.00	3.05E-04
20.00	2.92E-04
22.00	2.79E-04
24.00	2.67E-04
26.00	2.56E-04
28.00	2.45E-04
30.00	2.36E-04
32.00	2.27E-04
34.00	2.18E-04
36.00	2.10E-04
38.00	2.03E-04
40.00	1.96E-04

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	C_T	**3.30E-03**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.10E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	1.00E+01	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Based on measurement in BHG*
Distance to compliance point	x	4.00E+01	m	*Estimated*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	4.00E+00	m	*see options*
Transverse dispersivity	az	4.00E-01	m	*see options*
Vertical dispersivity	ay	4.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	5.55E-104	d^{-1}
Rate of contaminant flow due to retardation	u	1.19E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	7.83E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**2.68E+00**	

Remedial Targets

Remedial Target		**8.85E-03**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**40**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**7.83E+00**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

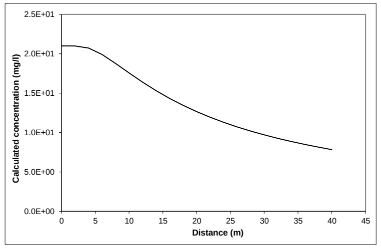
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	4.00E+00	2.59E+00	m
Transverse dispersivity	**az**	0.00E+00	4.00E-01	2.59E-01	m
Vertical dispersivity	**ay**	0.00E+00	4.00E-02	2.59E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run A

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.1E+01**
2.0	**2.10E+01**
4.0	**2.07E+01**
6.0	**1.99E+01**
8.0	**1.88E+01**
10.0	**1.76E+01**
12.0	**1.64E+01**
14.0	**1.53E+01**
16.0	**1.43E+01**
18.0	**1.35E+01**
20.0	**1.27E+01**
22.0	**1.19E+01**
24.0	**1.13E+01**
26.0	**1.07E+01**
28.0	**1.02E+01**
30.0	**9.70E+00**
32.0	**9.26E+00**
34.0	**8.86E+00**
36.0	**8.49E+00**
38.0	**8.15E+00**
40.0	**7.83E+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.

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

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:	**Former Chamber Bus Depot**		
Site Address:	**Church Square Bures CO8 5AB**		
Completed by:	**Rachel Foord**		
Date:	**20-Apr-23**	**Version:**	**Run G**
Contaminant	**Aro C16 - C21**		
Target Concentration (C_T)	**0.0033** mg/l	**Origin of C_T:**	**Uk Drinking Water Standard**

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 comparision 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		**Aro C16 - C21**	
Target concentration	C_T	**0.0033**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	1.30E-02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**9.01E+01**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**2.98E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0033	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run G

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16 - C21**		from Level 1
Target concentration	C_T	**0.0033**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.03E-03	m/d	**Met Office rainfall data 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	1.00E+01	m	**Estimated from site width of yard**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.10E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.75E+01**		
Level 2 Remedial Target		**9.08E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		8.19E+00	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run G

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aro C16 - C21		from Level 1
Target Concentration	C_T	**0.0033**	mg/l	from Level 1
Dilution Factor	**DF**	**2.75E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**1100**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	1.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.10E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.87E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	4.00E+01	m	*Assessed*
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	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	4.000	m	*see options*
Transverse dispersivity	az	0.400	m	*see options*
Vertical dispersivity	ay	0.040	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.72E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	4.99E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.87E-03	fraction
Rate of contaminant flow due to retardation	u	1.24E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.87E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**3.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.22E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**3.16E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		2.85E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**40**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**2.87E-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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

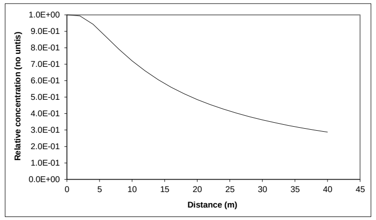
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	4.00E+00	2.59E+00	m
Transverse dispersivity	**az**	0.00E+00	4.00E-01	2.59E-01	m
Vertical dispersivity	**ay**	0.00E+00	4.00E-02	2.59E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run G

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	4.43E-01
2.0	9.94E-01	4.40E-01
4.0	9.43E-01	4.18E-01
6.0	8.68E-01	3.84E-01
8.0	7.91E-01	3.50E-01
10.0	7.21E-01	3.19E-01
12.0	6.60E-01	2.92E-01
14.0	6.06E-01	2.69E-01
16.0	5.60E-01	2.48E-01
18.0	5.20E-01	2.31E-01
20.0	4.85E-01	2.15E-01
22.0	4.55E-01	2.01E-01
24.0	4.27E-01	1.89E-01
26.0	4.03E-01	1.79E-01
28.0	3.81E-01	1.69E-01
30.0	3.62E-01	1.60E-01
32.0	3.44E-01	1.52E-01
34.0	3.28E-01	1.45E-01
36.0	3.13E-01	1.39E-01
38.0	3.00E-01	1.33E-01
40.0	2.87E-01	1.27E-01

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	1.00E+00	mg/kg

Level 1 Parameters

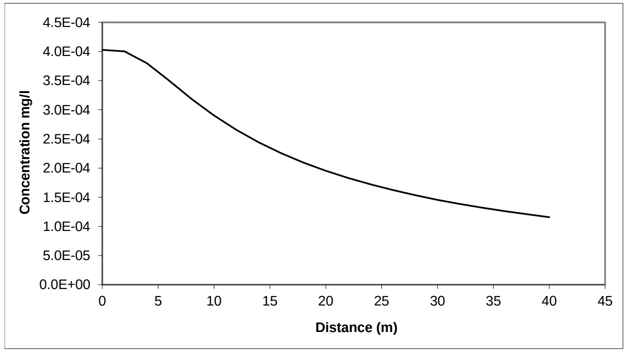
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.01E+01	l/kg
Factor (partitioning between soil and water)		9.02E+01	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	2.75E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	3.48E+00

Predicted concentrations at compliance point

Level 1	C	1.11E-02	mg/l	No dilution or attenuation
Level 2	C	4.03E-04	mg/l	Dilution taken into account
Level 3	C	1.16E-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	4.03E-04
2.00	4.00E-04
4.00	3.80E-04
6.00	3.50E-04
8.00	3.19E-04
10.00	2.90E-04
12.00	2.66E-04
14.00	2.44E-04
16.00	2.26E-04
18.00	2.10E-04
20.00	1.96E-04
22.00	1.83E-04
24.00	1.72E-04
26.00	1.62E-04
28.00	1.54E-04
30.00	1.46E-04
32.00	1.39E-04
34.00	1.32E-04
36.00	1.26E-04
38.00	1.21E-04
40.00	1.16E-04

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Environment Agency

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	C_T	**3.30E-03**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.10E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Based on measurement in BHG*
Distance to compliance point	x	4.00E+01	m	*Estimated*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*

Parameters values determined from options

Partition coefficient	Kd	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	4.00E+00	m	*see options*
Transverse dispersivity	az	4.00E-01	m	*see options*
Vertical dispersivity	ay	4.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	5.55E-104	d^{-1}
Rate of contaminant flow due to retardation	u	1.19E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	4.29E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**4.90E+00**	

Remedial Targets

Remedial Target		**1.62E-02**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**40**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**4.29E+00**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

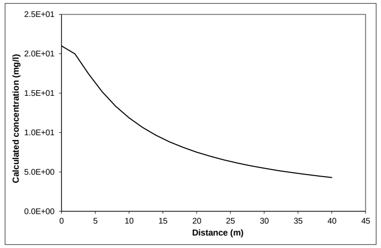
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	4.00E+00	2.59E+00	m
Transverse dispersivity	**az**	0.00E+00	4.00E-01	2.59E-01	m
Vertical dispersivity	**ay**	0.00E+00	4.00E-02	2.59E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run G

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.1E+01**
2.0	**2.00E+01**
4.0	**1.75E+01**
6.0	**1.52E+01**
8.0	**1.34E+01**
10.0	**1.19E+01**
12.0	**1.07E+01**
14.0	**9.65E+00**
16.0	**8.82E+00**
18.0	**8.12E+00**
20.0	**7.51E+00**
22.0	**6.99E+00**
24.0	**6.54E+00**
26.0	**6.14E+00**
28.0	**5.78E+00**
30.0	**5.47E+00**
32.0	**5.18E+00**
34.0	**4.93E+00**
36.0	**4.69E+00**
38.0	**4.48E+00**
40.0	**4.29E+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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**20-Apr-23**		**Version:**	**Run K**
Contaminant	**Aro C16 - C21**			
Target Concentration (C_T)	**0.0033**	**mg/l**	**Origin of C_T:**	**Uk Drinking Water Standard**

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 comparision 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

Environment Agency

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		**Aro C16 - C21**		
Target concentration	**C_T**	**0.0033**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	1.30E-02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**9.01E+01**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**2.98E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0033	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run K

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16 - C21**		from Level 1
Target concentration	C_T	**0.0033**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		2.30E+01	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run K

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	**C_T**	**0.0033**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**1100**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	4.99E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	1.21E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.22E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		3.39E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

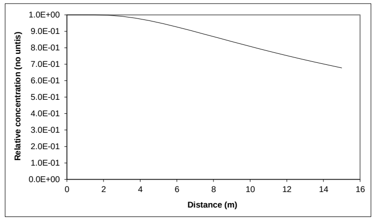
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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: Former Chamber Bus Depot
Completed by: Rachel Foord
Date: #######
Version: Run K

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Relative concentration (No units)**	**Concentration mg/l**
0	**1.0E+00**	**1.58E-01**
0.8	**1.00E+00**	**1.58E-01**
1.5	**1.00E+00**	**1.58E-01**
2.3	**9.98E-01**	**1.58E-01**
3.0	**9.91E-01**	**1.57E-01**
3.8	**9.80E-01**	**1.55E-01**
4.5	**9.65E-01**	**1.53E-01**
5.3	**9.47E-01**	**1.50E-01**
6.0	**9.27E-01**	**1.47E-01**
6.8	**9.05E-01**	**1.43E-01**
7.5	**8.83E-01**	**1.40E-01**
8.3	**8.60E-01**	**1.36E-01**
9.0	**8.38E-01**	**1.33E-01**
9.8	**8.16E-01**	**1.29E-01**
10.5	**7.94E-01**	**1.26E-01**
11.3	**7.73E-01**	**1.22E-01**
12.0	**7.52E-01**	**1.19E-01**
12.8	**7.33E-01**	**1.16E-01**
13.5	**7.14E-01**	**1.13E-01**
14.3	**6.95E-01**	**1.10E-01**
15.0	**6.78E-01**	**1.07E-01**

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	1.00E+00	mg/kg

Level 1 Parameters

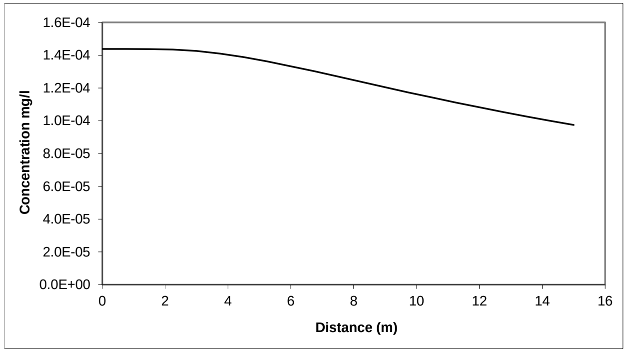
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.01E+01	l/kg
Factor (partitioning between soil and water)		9.02E+01	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	1.11E-02	mg/l	No dilution or attenuation
Level 2	C	1.44E-04	mg/l	Dilution taken into account
Level 3	C	9.74E-05	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.44E-04
0.75	1.44E-04
1.50	1.44E-04
2.25	1.43E-04
3.00	1.43E-04
3.75	1.41E-04
4.50	1.39E-04
5.25	1.36E-04
6.00	1.33E-04
6.75	1.30E-04
7.50	1.27E-04
8.25	1.24E-04
9.00	1.20E-04
9.75	1.17E-04
10.50	1.14E-04
11.25	1.11E-04
12.00	1.08E-04
12.75	1.05E-04
13.50	1.03E-04
14.25	1.00E-04
15.00	9.74E-05

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	C_T	**3.30E-03**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.10E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Based on measurement in BHG*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	5.55E-104	d^{-1}
Rate of contaminant flow due to retardation	u	1.19E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.56E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-03**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.56E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

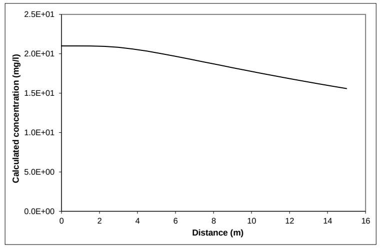
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run K

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.1E+01**
0.8	**2.10E+01**
1.5	**2.10E+01**
2.3	**2.10E+01**
3.0	**2.08E+01**
3.8	**2.06E+01**
4.5	**2.03E+01**
5.3	**2.00E+01**
6.0	**1.97E+01**
6.8	**1.93E+01**
7.5	**1.90E+01**
8.3	**1.86E+01**
9.0	**1.82E+01**
9.8	**1.79E+01**
10.5	**1.75E+01**
11.3	**1.72E+01**
12.0	**1.68E+01**
12.8	**1.65E+01**
13.5	**1.62E+01**
14.3	**1.59E+01**
15.0	**1.56E+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.

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

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:	**Former Chamber Bus Depot**		
Site Address:	**Church Square Bures CO8 5AB**		
Completed by:	**Rachel Foord**		
Date:	**20-Apr-23**	**Version:**	**Run L**
Contaminant	**Aro C16 - C21**		
Target Concentration (C_T)	**0.33** mg/l	**Origin of C_T:**	**Based on 1mg/l minimum effective clean up**

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 comparision 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

Environment Agency

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		**Aro C16 - C21**	
Target concentration	C_T	**0.33**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	1.30E-02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**9.01E+01**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**2.98E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.33	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run L

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16 - C21**		from Level 1
Target concentration	C_T	**0.33**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E+01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		2.30E+03	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run L

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	**C_T**	**0.33**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**1100**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	4.99E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	1.21E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.22E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		3.39E+03	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

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

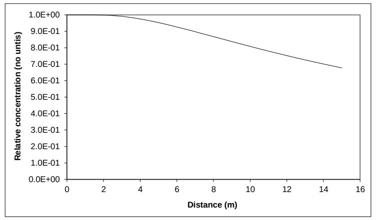
		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	m

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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used

Environment Agency



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run L

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.58E-01
0.8	1.00E+00	1.58E-01
1.5	1.00E+00	1.58E-01
2.3	9.98E-01	1.58E-01
3.0	9.91E-01	1.57E-01
3.8	9.80E-01	1.55E-01
4.5	9.65E-01	1.53E-01
5.3	9.47E-01	1.50E-01
6.0	9.27E-01	1.47E-01
6.8	9.05E-01	1.43E-01
7.5	8.83E-01	1.40E-01
8.3	8.60E-01	1.36E-01
9.0	8.38E-01	1.33E-01
9.8	8.16E-01	1.29E-01
10.5	7.94E-01	1.26E-01
11.3	7.73E-01	1.22E-01
12.0	7.52E-01	1.19E-01
12.8	7.33E-01	1.16E-01
13.5	7.14E-01	1.13E-01
14.3	6.95E-01	1.10E-01
15.0	6.78E-01	1.07E-01

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	1.00E+00	mg/kg

Level 1 Parameters

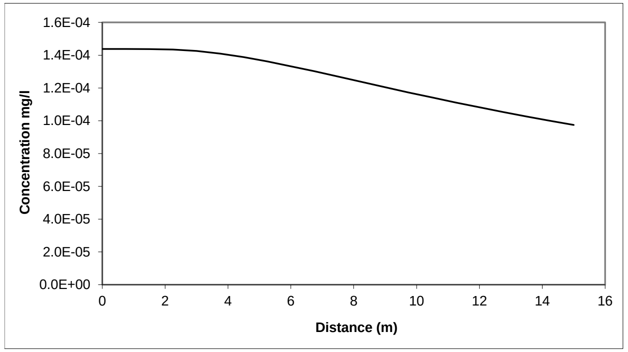
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	9.01E+01	l/kg
Factor (partitioning between soil and water)		9.02E+01	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	1.11E-02	mg/l	No dilution or attenuation
Level 2	C	1.44E-04	mg/l	Dilution taken into account
Level 3	C	9.74E-05	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.44E-04
0.75	1.44E-04
1.50	1.44E-04
2.25	1.43E-04
3.00	1.43E-04
3.75	1.41E-04
4.50	1.39E-04
5.25	1.36E-04
6.00	1.33E-04
6.75	1.30E-04
7.50	1.27E-04
8.25	1.24E-04
9.00	1.20E-04
9.75	1.17E-04
10.50	1.14E-04
11.25	1.11E-04
12.00	1.08E-04
12.75	1.05E-04
13.50	1.03E-04
14.25	1.00E-04
15.00	9.74E-05

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	**C_T**	**3.30E-01**	mg/l	from Level 1

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

Ogata Banks **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.10E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Based on measurement in BHG*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	5.55E-104	d^{-1}
Rate of contaminant flow due to retardation	u	1.19E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.56E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**1.56E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

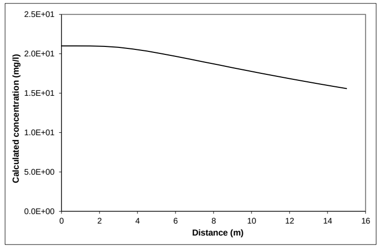
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run L

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.1E+01**
0.8	**2.10E+01**
1.5	**2.10E+01**
2.3	**2.10E+01**
3.0	**2.08E+01**
3.8	**2.06E+01**
4.5	**2.03E+01**
5.3	**2.00E+01**
6.0	**1.97E+01**
6.8	**1.93E+01**
7.5	**1.90E+01**
8.3	**1.86E+01**
9.0	**1.82E+01**
9.8	**1.79E+01**
10.5	**1.75E+01**
11.3	**1.72E+01**
12.0	**1.68E+01**
12.8	**1.65E+01**
13.5	**1.62E+01**
14.3	**1.59E+01**
15.0	**1.56E+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.

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

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: **Former Chamber Bus Depot**
Site Address: **Church Square Bures CO8 5AB**

Completed by: **Rachel Foord**
Date: **20-Apr-23** **Version:** **Run M**

Contaminant **Aro C16 - C21**
Target Concentration (C_T) **0.09** **mg/l** **Origin of C_T:** **Based on WHO DWS 0.09mg/l**

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 comparision 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		**Aro C16 - C21**	
Target concentration	C_T	**0.09**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	1.30E-02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**9.01E+01**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**8.12E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.09	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run M

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16 - C21**		from Level 1
Target concentration	C_T	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**6.94E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		6.26E+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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run M

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	C_T	**0.09**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**1100**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	4.99E-104	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	1.21E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.22E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**1.02E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		9.24E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

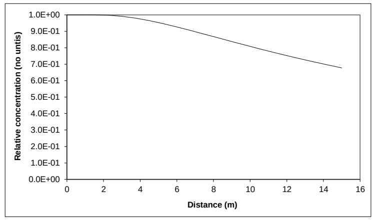
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	########
Version:	Run M

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	**1.0E+00**	**1.58E-01**
0.8	**1.00E+00**	**1.58E-01**
1.5	**1.00E+00**	**1.58E-01**
2.3	**9.98E-01**	**1.58E-01**
3.0	**9.91E-01**	**1.57E-01**
3.8	**9.80E-01**	**1.55E-01**
4.5	**9.65E-01**	**1.53E-01**
5.3	**9.47E-01**	**1.50E-01**
6.0	**9.27E-01**	**1.47E-01**
6.8	**9.05E-01**	**1.43E-01**
7.5	**8.83E-01**	**1.40E-01**
8.3	**8.60E-01**	**1.36E-01**
9.0	**8.38E-01**	**1.33E-01**
9.8	**8.16E-01**	**1.29E-01**
10.5	**7.94E-01**	**1.26E-01**
11.3	**7.73E-01**	**1.22E-01**
12.0	**7.52E-01**	**1.19E-01**
12.8	**7.33E-01**	**1.16E-01**
13.5	**7.14E-01**	**1.13E-01**
14.3	**6.95E-01**	**1.10E-01**
15.0	**6.78E-01**	**1.07E-01**

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

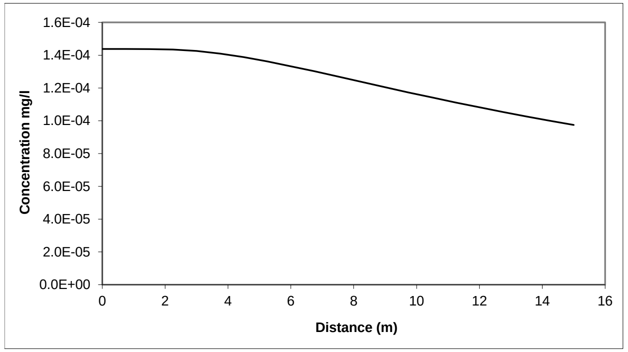
Only input required is Soil Contaminant Concentration

	Input Parameters			
	Soil contaminant concentration	C_0	1.00E+00	mg/kg
Level 1 Parameters				
	Water filled soil porosity	θ_W	1.52E-01	fraction
	Air filled soil porosity	θa	1.40E-01	fraction
	Bulk density	ρ	1.97E+00	g/cm^3
	Henry's Law constant	H	1.30E-02	dimensionless
	Soil water partition coefficient used in Level Assessment	Kd	9.01E+01	l/kg
	Factor (partitioning between soil and water)		9.02E+01	dimensionless
Level 2 Parameters	**Dilution Factor**	DF	7.71E+01	
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00	

Predicted concentrations at compliance point

Level 1	C	1.11E-02	mg/l	No dilution or attenuation
Level 2	C	1.44E-04	mg/l	Dilution taken into account
Level 3	C	9.74E-05	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	1.44E-04
0.75	1.44E-04
1.50	1.44E-04
2.25	1.43E-04
3.00	1.43E-04
3.75	1.41E-04
4.50	1.39E-04
5.25	1.36E-04
6.00	1.33E-04
6.75	1.30E-04
7.50	1.27E-04
8.25	1.24E-04
9.00	1.20E-04
9.75	1.17E-04
10.50	1.14E-04
11.25	1.11E-04
12.00	1.08E-04
12.75	1.05E-04
13.50	1.03E-04
14.25	1.00E-04
15.00	9.74E-05

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	C_T	**9.00E-02**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.10E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Based on measurement in BHG*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.01E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.39E+03	fraction
Decay rate used	λ	5.55E-104	d^{-1}
Rate of contaminant flow due to retardation	u	1.19E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.56E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**1.21E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.56E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	9.01E+01	l/kg

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

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

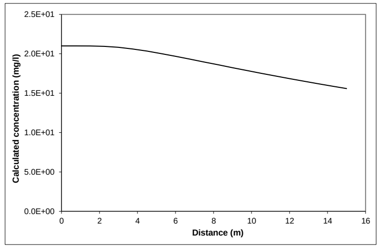
		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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

Environment Agency



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed: Former Chamber Bus Depot
Completed by: Rachel Foord
Date: #######
Version: Run M

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.1E+01**
0.8	**2.10E+01**
1.5	**2.10E+01**
2.3	**2.10E+01**
3.0	**2.08E+01**
3.8	**2.06E+01**
4.5	**2.03E+01**
5.3	**2.00E+01**
6.0	**1.97E+01**
6.8	**1.93E+01**
7.5	**1.90E+01**
8.3	**1.86E+01**
9.0	**1.82E+01**
9.8	**1.79E+01**
10.5	**1.75E+01**
11.3	**1.72E+01**
12.0	**1.68E+01**
12.8	**1.65E+01**
13.5	**1.62E+01**
14.3	**1.59E+01**
15.0	**1.56E+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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**20-Apr-23**		**Version:**	**Run O**
Contaminant	**Aro C16 - C21**			
Target Concentration (C_T)	**0.33**	**mg/l**	**Origin of C_T:**	**Based on minimum clean up 1mg/l**

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 comparision 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		**Aro C16 - C21**		
Target concentration	C_T	**0.33**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	1.30E-02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	[redacted]	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	2.32E-03	fraction	Soil Organic matter 0.4%
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$	[redacted]	l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg	
pH value	pH	[redacted]	pH units	
Acid dissociation constant	pKa	[redacted]		
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**3.28E+01**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**1.08E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.33	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Aro C16 - C21**		from Level 1
Target concentration	**C_T**	**0.33**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data, 100% hardstanding drains**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E+01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		8.36E+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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	**C_T**	**0.33**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**1100**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	
Calculated decay rate	λ	7.70E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	3.28E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	5.06E+02	fraction
Decay rate used	λ	1.52E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	3.32E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	3.35E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.23E+03	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**6.78E-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	foc	2.32E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.28E+01	l/kg

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

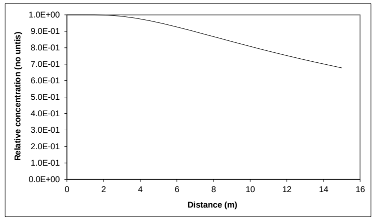
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run O

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	4.34E-01
0.8	1.00E+00	4.34E-01
1.5	1.00E+00	4.34E-01
2.3	9.98E-01	4.33E-01
3.0	9.91E-01	4.30E-01
3.8	9.80E-01	4.26E-01
4.5	9.65E-01	4.19E-01
5.3	9.47E-01	4.11E-01
6.0	9.27E-01	4.03E-01
6.8	9.05E-01	3.93E-01
7.5	8.83E-01	3.83E-01
8.3	8.60E-01	3.74E-01
9.0	8.38E-01	3.64E-01
9.8	8.16E-01	3.54E-01
10.5	7.94E-01	3.45E-01
11.3	7.73E-01	3.36E-01
12.0	7.52E-01	3.27E-01
12.8	7.33E-01	3.18E-01
13.5	7.14E-01	3.10E-01
14.3	6.95E-01	3.02E-01
15.0	6.78E-01	2.94E-01

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	1.00E+00	mg/kg

Level 1 Parameters

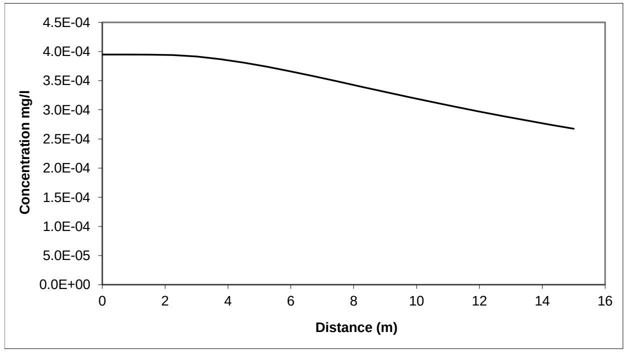
Water filled soil porosity	θ_w	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	1.30E-02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.28E+01	l/kg
Factor (partitioning between soil and water)		3.28E+01	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	3.04E-02	mg/l	No dilution or attenuation
Level 2	C	3.95E-04	mg/l	Dilution taken into account
Level 3	C	2.68E-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	3.95E-04
0.75	3.95E-04
1.50	3.95E-04
2.25	3.94E-04
3.00	3.91E-04
3.75	3.87E-04
4.50	3.81E-04
5.25	3.74E-04
6.00	3.66E-04
6.75	3.57E-04
7.50	3.49E-04
8.25	3.40E-04
9.00	3.31E-04
9.75	3.22E-04
10.50	3.13E-04
11.25	3.05E-04
12.00	2.97E-04
12.75	2.89E-04
13.50	2.82E-04
14.25	2.75E-04
15.00	2.68E-04

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Aro C16 - C21**		from Level 1
Target Concentration	C_T	**3.30E-01**	mg/l	from Level 1

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

Ogata Banks **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.10E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Based on measurement in BHG*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.28E+01	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	5.06E+02	fraction
Decay rate used	λ	1.52E-103	d^{-1}
Rate of contaminant flow due to retardation	u	3.27E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.56E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.56E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	2.32E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.28E+01	l/kg

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

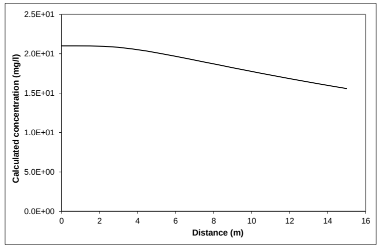
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run O

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.1E+01**
0.8	**2.10E+01**
1.5	**2.10E+01**
2.3	**2.10E+01**
3.0	**2.08E+01**
3.8	**2.06E+01**
4.5	**2.03E+01**
5.3	**2.00E+01**
6.0	**1.97E+01**
6.8	**1.93E+01**
7.5	**1.90E+01**
8.3	**1.86E+01**
9.0	**1.82E+01**
9.8	**1.79E+01**
10.5	**1.75E+01**
11.3	**1.72E+01**
12.0	**1.68E+01**
12.8	**1.65E+01**
13.5	**1.62E+01**
14.3	**1.59E+01**
15.0	**1.56E+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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**20-Apr-23**		**Version:**	**Run K**
Contaminant	**Ali C12 - C16**			
Target Concentration (C_T)	**0.0033**	**mg/l**	**Origin of C_T:**	**Uk Drinking Water Standard**

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 comparision 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		**Ali C12 - C16**	
Target concentration	C_T	**0.0033**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	5.20E+02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	[redacted]	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$	[redacted]	l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg	
pH value	pH	[redacted]	pH units	
Acid dissociation constant	pKa	[redacted]		
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**3.43E+04**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**1.13E+02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0033	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run K

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C12 - C16**		from Level 1
Target concentration	C_T	**0.0033**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data, 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 20x20m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site measurement**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		8.73E+03	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run K

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters

Input Parameters	Variable	Value	Unit	Source
Contaminant		Ali C12 - C16		from Level 1
Target Concentration	C_T	0.0033	mg/l	from Level 1
Dilution Factor	DF	7.71E+01		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		**Soil concentration as mg/kg**		
Enter soil concentration		2900	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	3.43E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	5.28E+05	fraction
Decay rate used	λ	1.31E-106	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	3.18E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	8.45E-02	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.29E+04	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.43E+04	l/kg

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

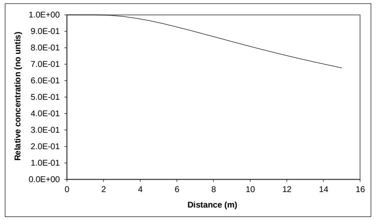
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run K

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Relative concentration (No units)**	**Concentration mg/l**
0	**1.0E+00**	**1.10E-03**
0.8	**1.00E+00**	**1.10E-03**
1.5	**1.00E+00**	**1.10E-03**
2.3	**9.98E-01**	**1.09E-03**
3.0	**9.91E-01**	**1.09E-03**
3.8	**9.80E-01**	**1.07E-03**
4.5	**9.65E-01**	**1.06E-03**
5.3	**9.47E-01**	**1.04E-03**
6.0	**9.27E-01**	**1.02E-03**
6.8	**9.05E-01**	**9.93E-04**
7.5	**8.83E-01**	**9.68E-04**
8.3	**8.60E-01**	**9.43E-04**
9.0	**8.38E-01**	**9.19E-04**
9.8	**8.16E-01**	**8.94E-04**
10.5	**7.94E-01**	**8.71E-04**
11.3	**7.73E-01**	**8.47E-04**
12.0	**7.52E-01**	**8.25E-04**
12.8	**7.33E-01**	**8.03E-04**
13.5	**7.14E-01**	**7.82E-04**
14.3	**6.95E-01**	**7.62E-04**
15.0	**6.78E-01**	**7.43E-04**

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	1.00E+00	mg/kg

Level 1 Parameters

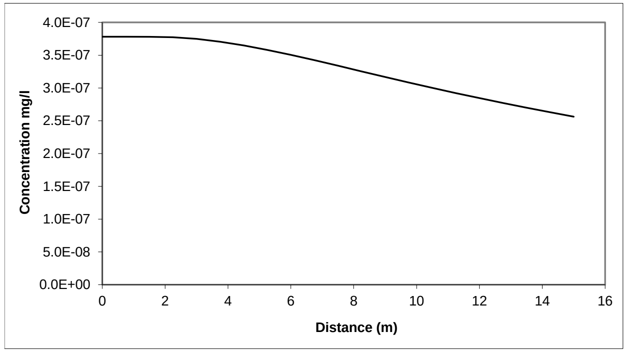
Water filled soil porosity	θ_w	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	5.20E+02	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.43E+04	l/kg
Factor (partitioning between soil and water)		3.43E+04	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	2.92E-05	mg/l	No dilution or attenuation
Level 2	C	3.78E-07	mg/l	Dilution taken into account
Level 3	C	2.56E-07	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-07
0.75	3.78E-07
1.50	3.78E-07
2.25	3.77E-07
3.00	3.75E-07
3.75	3.71E-07
4.50	3.65E-07
5.25	3.58E-07
6.00	3.50E-07
6.75	3.42E-07
7.50	3.34E-07
8.25	3.25E-07
9.00	3.17E-07
9.75	3.08E-07
10.50	3.00E-07
11.25	2.92E-07
12.00	2.84E-07
12.75	2.77E-07
13.50	2.70E-07
14.25	2.63E-07
15.00	2.56E-07

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	C_T	**3.30E-03**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.80E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.43E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	5.28E+05	fraction
Decay rate used	λ	1.46E-106	d^{-1}
Rate of contaminant flow due to retardation	u	3.14E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.34E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-03**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.34E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.43E+04	l/kg

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

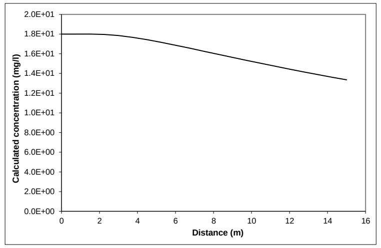
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run K

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**1.8E+01**
0.8	**1.80E+01**
1.5	**1.80E+01**
2.3	**1.80E+01**
3.0	**1.78E+01**
3.8	**1.77E+01**
4.5	**1.74E+01**
5.3	**1.72E+01**
6.0	**1.69E+01**
6.8	**1.66E+01**
7.5	**1.63E+01**
8.3	**1.59E+01**
9.0	**1.56E+01**
9.8	**1.53E+01**
10.5	**1.50E+01**
11.3	**1.47E+01**
12.0	**1.44E+01**
12.8	**1.42E+01**
13.5	**1.39E+01**
14.3	**1.36E+01**
15.0	**1.34E+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.

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

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: Former Chamber Bus Depot
Site Address: Church Square Bures CO8 5AB

Completed by: Rachel Foord
Date: 20-Apr-23 **Version:** Run O

Contaminant Ali C12 - C16
Target Concentration (C_T) 0.33 mg/l **Origin of C_T:** Based on 1mg/l effective clean up

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 comparision 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

Environment Agency

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		**Ali C12 - C16**		
Target concentration	C_T	**0.33**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	5.20E+02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	2.32E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**1.25E+04**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**4.12E+03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.33	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C12 - C16**		from Level 1
Target concentration	C_T	**0.33**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 20x20m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site measurement**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E+01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		3.18E+05	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	**C_T**	**0.33**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**2900**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	1.25E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	1.92E+05	fraction
Decay rate used	λ	3.61E-106	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	8.74E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	2.32E-01	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.69E+05	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**6.78E-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	foc	2.32E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	1.25E+04	l/kg

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

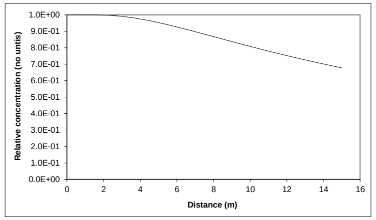
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run O

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	**1.0E+00**	**3.01E-03**
0.8	**1.00E+00**	**3.01E-03**
1.5	**1.00E+00**	**3.01E-03**
2.3	**9.98E-01**	**3.00E-03**
3.0	**9.91E-01**	**2.98E-03**
3.8	**9.80E-01**	**2.95E-03**
4.5	**9.65E-01**	**2.90E-03**
5.3	**9.47E-01**	**2.85E-03**
6.0	**9.27E-01**	**2.79E-03**
6.8	**9.05E-01**	**2.72E-03**
7.5	**8.83E-01**	**2.66E-03**
8.3	**8.60E-01**	**2.59E-03**
9.0	**8.38E-01**	**2.52E-03**
9.8	**8.16E-01**	**2.45E-03**
10.5	**7.94E-01**	**2.39E-03**
11.3	**7.73E-01**	**2.33E-03**
12.0	**7.52E-01**	**2.26E-03**
12.8	**7.33E-01**	**2.20E-03**
13.5	**7.14E-01**	**2.15E-03**
14.3	**6.95E-01**	**2.09E-03**
15.0	**6.78E-01**	**2.04E-03**

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

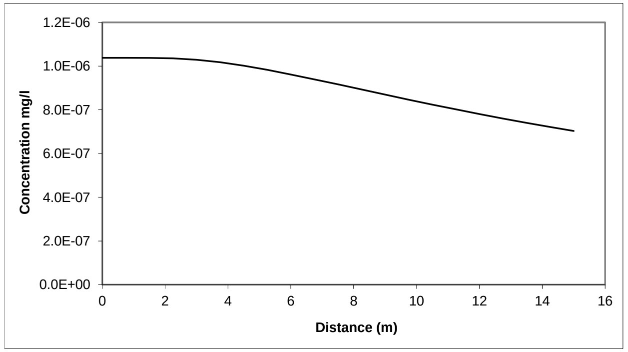
Only input required is Soil Contaminant Concentration

	Input Parameters			
	Soil contaminant concentration	C_0	1.00E+00	mg/kg
Level 1 Parameters				
	Water filled soil porosity	θ_w	1.52E-01	fraction
	Air filled soil porosity	θa	1.40E-01	fraction
	Bulk density	ρ	1.97E+00	g/cm^3
	Henry's Law constant	H	5.20E+02	dimensionless
	Soil water partition coefficient used in Level Assessment	Kd	1.25E+04	l/kg
	Factor (partitioning between soil and water)		1.25E+04	dimensionless
Level 2 Parameters	**Dilution Factor**	DF	7.71E+01	
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00	

Predicted concentrations at compliance point

Level 1	C	8.00E-05	mg/l	No dilution or attenuation
Level 2	C	1.04E-06	mg/l	Dilution taken into account
Level 3	C	7.03E-07	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-06
0.75	1.04E-06
1.50	1.04E-06
2.25	1.04E-06
3.00	1.03E-06
3.75	1.02E-06
4.50	1.00E-06
5.25	9.83E-07
6.00	9.62E-07
6.75	9.39E-07
7.50	9.16E-07
8.25	8.93E-07
9.00	8.70E-07
9.75	8.46E-07
10.50	8.24E-07
11.25	8.02E-07
12.00	7.81E-07
12.75	7.60E-07
13.50	7.41E-07
14.25	7.22E-07
15.00	7.03E-07

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Environment Agency

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	C_T	**3.30E-01**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	1.80E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.25E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.92E+05	fraction
Decay rate used	λ	4.01E-106	d^{-1}
Rate of contaminant flow due to retardation	u	8.63E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.34E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.34E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	2.32E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	1.25E+04	l/kg

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

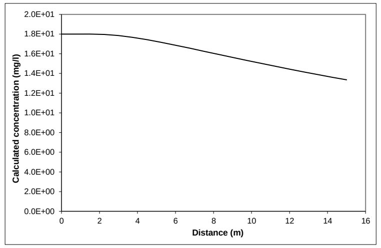
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed: Former Chamber Bus Depot
Completed by: Rachel Foord
Date: #######
Version: Run O

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**1.8E+01**
0.8	**1.80E+01**
1.5	**1.80E+01**
2.3	**1.80E+01**
3.0	**1.78E+01**
3.8	**1.77E+01**
4.5	**1.74E+01**
5.3	**1.72E+01**
6.0	**1.69E+01**
6.8	**1.66E+01**
7.5	**1.63E+01**
8.3	**1.59E+01**
9.0	**1.56E+01**
9.8	**1.53E+01**
10.5	**1.50E+01**
11.3	**1.47E+01**
12.0	**1.44E+01**
12.8	**1.42E+01**
13.5	**1.39E+01**
14.3	**1.36E+01**
15.0	**1.34E+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.

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

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: Former Chamber Bus Depot
Site Address: Church Square Bures CO8 5AB

Completed by: Rachel Foord
Date: 20-Apr-23 **Version:** Run M

Contaminant Ali C12 - C16
Target Concentration (C_T) 0.1 mg/l **Origin of C_T:** Based on WHO guide value 0.3mg/l

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 comparision 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		**Ali C12 - C16**	
Target concentration	C_T	**0.1**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	5.20E+02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**3.43E+04**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**3.43E+03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.1	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run M

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C12 - C16**		from Level 1
Target concentration	C_T	**0.1**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data, 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 20x20m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site measurement**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**7.71E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		2.64E+05	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run M

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	C_T	**0.1**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**2900**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	3.43E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	5.28E+05	fraction
Decay rate used	λ	1.31E-106	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	3.18E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	8.45E-02	mg/l

Remedial Targets

Level 3 Remedial Target		**1.14E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		3.90E+05	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.43E+04	l/kg

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

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

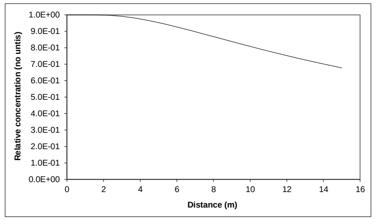
		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	m

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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used

Environment Agency



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run M

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.10E-03
0.8	1.00E+00	1.10E-03
1.5	1.00E+00	1.10E-03
2.3	9.98E-01	1.09E-03
3.0	9.91E-01	1.09E-03
3.8	9.80E-01	1.07E-03
4.5	9.65E-01	1.06E-03
5.3	9.47E-01	1.04E-03
6.0	9.27E-01	1.02E-03
6.8	9.05E-01	9.93E-04
7.5	8.83E-01	9.68E-04
8.3	8.60E-01	9.43E-04
9.0	8.38E-01	9.19E-04
9.8	8.16E-01	8.94E-04
10.5	7.94E-01	8.71E-04
11.3	7.73E-01	8.47E-04
12.0	7.52E-01	8.25E-04
12.8	7.33E-01	8.03E-04
13.5	7.14E-01	7.82E-04
14.3	6.95E-01	7.62E-04
15.0	6.78E-01	7.43E-04

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

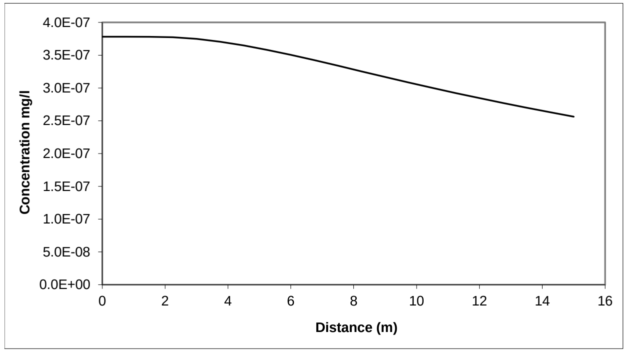
Only input required is Soil Contaminant Concentration

	Input Parameters			
	Soil contaminant concentration	C_0	1.00E+00	mg/kg
Level 1 Parameters				
	Water filled soil porosity	θ_W	1.52E-01	fraction
	Air filled soil porosity	θa	1.40E-01	fraction
	Bulk density	ρ	1.97E+00	g/cm^3
	Henry's Law constant	H	5.20E+02	dimensionless
	Soil water partition coefficient used in Level Assessment	Kd	3.43E+04	l/kg
	Factor (partitioning between soil and water)		3.43E+04	dimensionless
Level 2 Parameters	**Dilution Factor**	DF	7.71E+01	
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00	

Predicted concentrations at compliance point

Level 1	C	2.92E-05	mg/l	No dilution or attenuation
Level 2	C	3.78E-07	mg/l	Dilution taken into account
Level 3	C	2.56E-07	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-07
0.75	3.78E-07
1.50	3.78E-07
2.25	3.77E-07
3.00	3.75E-07
3.75	3.71E-07
4.50	3.65E-07
5.25	3.58E-07
6.00	3.50E-07
6.75	3.42E-07
7.50	3.34E-07
8.25	3.25E-07
9.00	3.17E-07
9.75	3.08E-07
10.50	3.00E-07
11.25	2.92E-07
12.00	2.84E-07
12.75	2.77E-07
13.50	2.70E-07
14.25	2.63E-07
15.00	2.56E-07

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Environment Agency

Input Parameters (using pull down menu)

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	C_T	**1.00E-01**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	1.80E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.43E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	5.28E+05	fraction
Decay rate used	λ	1.46E-106	d^{-1}
Rate of contaminant flow due to retardation	u	3.14E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.34E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**1.35E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**1.34E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.43E+04	l/kg

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

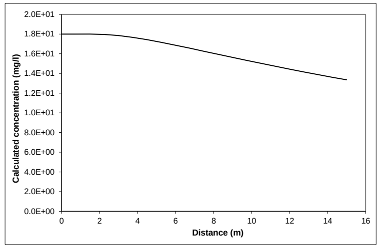
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run M

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**1.8E+01**
0.8	**1.80E+01**
1.5	**1.80E+01**
2.3	**1.80E+01**
3.0	**1.78E+01**
3.8	**1.77E+01**
4.5	**1.74E+01**
5.3	**1.72E+01**
6.0	**1.69E+01**
6.8	**1.66E+01**
7.5	**1.63E+01**
8.3	**1.59E+01**
9.0	**1.56E+01**
9.8	**1.53E+01**
10.5	**1.50E+01**
11.3	**1.47E+01**
12.0	**1.44E+01**
12.8	**1.42E+01**
13.5	**1.39E+01**
14.3	**1.36E+01**
15.0	**1.34E+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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**20-Apr-23**		**Version:**	**Run O**
Contaminant	**Ali C12 - C16**			
Target Concentration (C_T)	**0.33**	**mg/l**	**Origin of C_T:**	**Based on 1mg/l effective clean up**

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 comparision 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

Environment Agency

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		**Ali C12 - C16**		
Target concentration	C_T	**0.33**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porosity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porosity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	5.20E+02	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	2.32E-03	fraction	Soil organic matter 0.4%
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**1.25E+04**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**4.12E+03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.33	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C12 - C16**		from Level 1
Target concentration	C_T	**0.33**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 20x20m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on site measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on site measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site measurement**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E+01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		3.18E+05	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	**C_T**	**0.33**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**2900**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	1.25E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	1.92E+05	fraction
Decay rate used	λ	3.61E-106	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	8.74E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	2.32E-01	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.69E+05	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**6.78E-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	foc	2.32E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	1.25E+04	l/kg

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

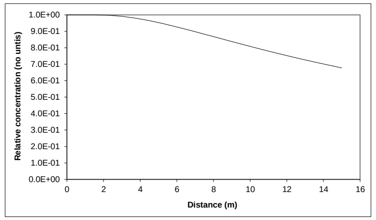
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run O

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	**1.0E+00**	**3.01E-03**
0.8	**1.00E+00**	**3.01E-03**
1.5	**1.00E+00**	**3.01E-03**
2.3	**9.98E-01**	**3.00E-03**
3.0	**9.91E-01**	**2.98E-03**
3.8	**9.80E-01**	**2.95E-03**
4.5	**9.65E-01**	**2.90E-03**
5.3	**9.47E-01**	**2.85E-03**
6.0	**9.27E-01**	**2.79E-03**
6.8	**9.05E-01**	**2.72E-03**
7.5	**8.83E-01**	**2.66E-03**
8.3	**8.60E-01**	**2.59E-03**
9.0	**8.38E-01**	**2.52E-03**
9.8	**8.16E-01**	**2.45E-03**
10.5	**7.94E-01**	**2.39E-03**
11.3	**7.73E-01**	**2.33E-03**
12.0	**7.52E-01**	**2.26E-03**
12.8	**7.33E-01**	**2.20E-03**
13.5	**7.14E-01**	**2.15E-03**
14.3	**6.95E-01**	**2.09E-03**
15.0	**6.78E-01**	**2.04E-03**

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

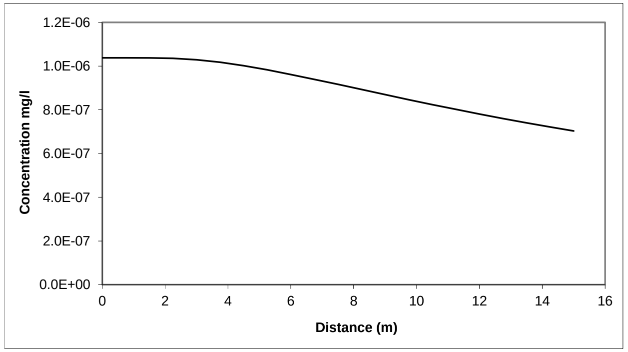
Only input required is Soil Contaminant Concentration

	Input Parameters			
	Soil contaminant concentration	C_0	1.00E+00	mg/kg
Level 1 Parameters				
	Water filled soil porosity	θ_W	1.52E-01	fraction
	Air filled soil porosity	θa	1.40E-01	fraction
	Bulk density	ρ	1.97E+00	g/cm^3
	Henry's Law constant	H	5.20E+02	dimensionless
	Soil water partition coefficient used in Level Assessment	Kd	1.25E+04	l/kg
	Factor (partitioning between soil and water)		1.25E+04	dimensionless
Level 2 Parameters	**Dilution Factor**	DF	7.71E+01	
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00	

Predicted concentrations at compliance point

Level 1	C	8.00E-05	mg/l	No dilution or attenuation
Level 2	C	1.04E-06	mg/l	Dilution taken into account
Level 3	C	7.03E-07	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-06
0.75	1.04E-06
1.50	1.04E-06
2.25	1.04E-06
3.00	1.03E-06
3.75	1.02E-06
4.50	1.00E-06
5.25	9.83E-07
6.00	9.62E-07
6.75	9.39E-07
7.50	9.16E-07
8.25	8.93E-07
9.00	8.70E-07
9.75	8.46E-07
10.50	8.24E-07
11.25	8.02E-07
12.00	7.81E-07
12.75	7.60E-07
13.50	7.41E-07
14.25	7.22E-07
15.00	7.03E-07

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C12 - C16**		from Level 1
Target Concentration	C_T	**3.30E-01**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	1.80E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.25E+04	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	1.92E+05	fraction
Decay rate used	λ	4.01E-106	d^{-1}
Rate of contaminant flow due to retardation	u	8.63E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.34E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**1.34E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	2.32E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	1.25E+04	l/kg

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

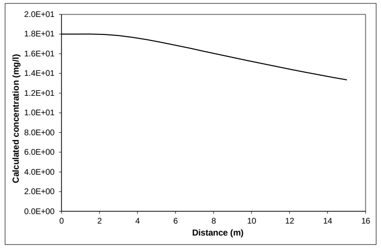
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run O

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**1.8E+01**
0.8	**1.80E+01**
1.5	**1.80E+01**
2.3	**1.80E+01**
3.0	**1.78E+01**
3.8	**1.77E+01**
4.5	**1.74E+01**
5.3	**1.72E+01**
6.0	**1.69E+01**
6.8	**1.66E+01**
7.5	**1.63E+01**
8.3	**1.59E+01**
9.0	**1.56E+01**
9.8	**1.53E+01**
10.5	**1.50E+01**
11.3	**1.47E+01**
12.0	**1.44E+01**
12.8	**1.42E+01**
13.5	**1.39E+01**
14.3	**1.36E+01**
15.0	**1.34E+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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**20-Apr-23**		**Version:**	**Run K**
Contaminant	**Ali C16 - C21**			
Target Concentration (C_T)	**0.0033**	**mg/l**	**Origin of C_T:**	**Uk Drinking Water Standard**

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 comparision 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

Environment Agency

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		**Ali C16 - C21**	
Target concentration	**C_T**	**0.0033**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porocity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porocity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	4.90E+03	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	5.75E+08	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**3.67E+06**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**1.21E+04**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0033	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run K

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C16 - C21**		from Level 1
Target concentration	C_T	**0.0033**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding drains**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		9.34E+05	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run K

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Ali C16 - C21		from Level 1
Target Concentration	C_T	0.0033	mg/l	from Level 1
Dilution Factor	DF	7.71E+01		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	**Soil concentration as mg/kg**			
Enter soil concentration		**3700**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	3.67E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	5.65E+07	fraction
Decay rate used	λ	1.23E-108	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	2.97E-08	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.01E-03	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.38E+06	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.67E+06	l/kg

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

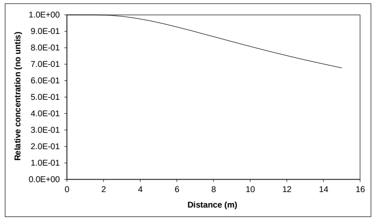
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run K

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.31E-05
0.8	1.00E+00	1.31E-05
1.5	1.00E+00	1.31E-05
2.3	9.98E-01	1.30E-05
3.0	9.91E-01	1.30E-05
3.8	9.80E-01	1.28E-05
4.5	9.65E-01	1.26E-05
5.3	9.47E-01	1.24E-05
6.0	9.27E-01	1.21E-05
6.8	9.05E-01	1.18E-05
7.5	8.83E-01	1.15E-05
8.3	8.60E-01	1.12E-05
9.0	8.38E-01	1.09E-05
9.8	8.16E-01	1.07E-05
10.5	7.94E-01	1.04E-05
11.3	7.73E-01	1.01E-05
12.0	7.52E-01	9.83E-06
12.8	7.33E-01	9.57E-06
13.5	7.14E-01	9.33E-06
14.3	6.95E-01	9.09E-06
15.0	6.78E-01	8.86E-06

Remedial Targets Worksheet , Release 3.2

Calculation of contaminant concentration in groundwater from a soil source

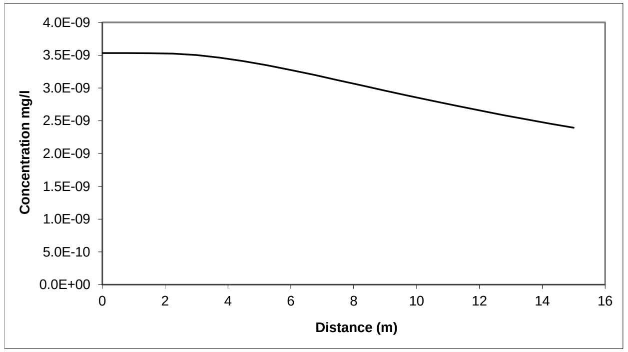
Only input required is Soil Contaminant Concentration

	Input Parameters			
	Soil contaminant concentration	C_0	1.00E+00	mg/kg
Level 1 Parameters				
	Water filled soil porosity	θ_W	1.52E-01	fraction
	Air filled soil porosity	θa	1.40E-01	fraction
	Bulk density	ρ	1.97E+00	g/cm^3
	Henry's Law constant	H	4.90E+03	dimensionless
	Soil water partition coefficient used in Level Assessment	Kd	3.67E+06	l/kg
	Factor (partitioning between soil and water)		3.67E+06	dimensionless
Level 2 Parameters	**Dilution Factor**	DF	7.71E+01	
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00	

Predicted concentrations at compliance point

Level 1	C	2.72E-07	mg/l	No dilution or attenuation
Level 2	C	3.53E-09	mg/l	Dilution taken into account
Level 3	C	2.39E-09	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.53E-09
0.75	3.53E-09
1.50	3.53E-09
2.25	3.52E-09
3.00	3.50E-09
3.75	3.46E-09
4.50	3.41E-09
5.25	3.35E-09
6.00	3.27E-09
6.75	3.20E-09
7.50	3.12E-09
8.25	3.04E-09
9.00	2.96E-09
9.75	2.88E-09
10.50	2.80E-09
11.25	2.73E-09
12.00	2.66E-09
12.75	2.59E-09
13.50	2.52E-09
14.25	2.46E-09
15.00	2.39E-09

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Environment Agency

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C16 - C21**		from Level 1
Target Concentration	**C_T**	**3.30E-03**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.40E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.67E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	5.65E+07	fraction
Decay rate used	λ	1.36E-108	d^{-1}
Rate of contaminant flow due to retardation	u	2.93E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.78E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-03**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	**C_{ED}/C_0**	**1.78E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.67E+06	l/kg

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

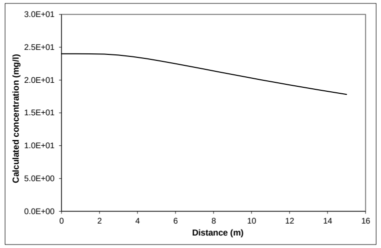
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run K

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.4E+01**
0.8	**2.40E+01**
1.5	**2.40E+01**
2.3	**2.39E+01**
3.0	**2.38E+01**
3.8	**2.36E+01**
4.5	**2.32E+01**
5.3	**2.29E+01**
6.0	**2.25E+01**
6.8	**2.21E+01**
7.5	**2.17E+01**
8.3	**2.13E+01**
9.0	**2.08E+01**
9.8	**2.04E+01**
10.5	**2.00E+01**
11.3	**1.96E+01**
12.0	**1.93E+01**
12.8	**1.89E+01**
13.5	**1.85E+01**
14.3	**1.82E+01**
15.0	**1.78E+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.

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

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: Former Chamber Bus Depot
Site Address: Church Square Bures CO8 5AB

Completed by: Rachel Foord
Date: 20-Apr-23 **Version:** Run L

Contaminant Ali C16 - C21
Target Concentration (C_T) 0.33 mg/l **Origin of C_T:** Based on 1mg/l effective clean up

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 comparision 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		**Ali C16 - C21**		
Target concentration	C_T	**0.33**	**mg/l**	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porocity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porocity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	4.90E+03	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	5.75E+08	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**3.67E+06**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**1.21E+06**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.33	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run L

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C16 - C21**		from Level 1
Target concentration	C_T	**0.33**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data, 100% hardstanding drains**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E+01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		9.34E+07	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run L

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Ali C16 - C21		from Level 1
Target Concentration	C_T	0.33	mg/l	from Level 1
Dilution Factor	DF	7.71E+01		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	**Soil concentration as mg/kg**			
Enter soil concentration		**3700**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	3.67E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	5.65E+07	fraction
Decay rate used	λ	1.23E-108	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	2.97E-08	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.01E-03	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.38E+08	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.67E+06	l/kg

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

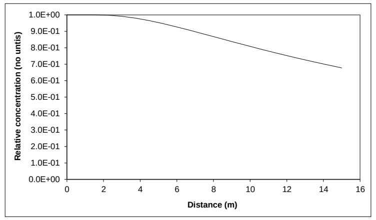
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run L

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.31E-05
0.8	1.00E+00	1.31E-05
1.5	1.00E+00	1.31E-05
2.3	9.98E-01	1.30E-05
3.0	9.91E-01	1.30E-05
3.8	9.80E-01	1.28E-05
4.5	9.65E-01	1.26E-05
5.3	9.47E-01	1.24E-05
6.0	9.27E-01	1.21E-05
6.8	9.05E-01	1.18E-05
7.5	8.83E-01	1.15E-05
8.3	8.60E-01	1.12E-05
9.0	8.38E-01	1.09E-05
9.8	8.16E-01	1.07E-05
10.5	7.94E-01	1.04E-05
11.3	7.73E-01	1.01E-05
12.0	7.52E-01	9.83E-06
12.8	7.33E-01	9.57E-06
13.5	7.14E-01	9.33E-06
14.3	6.95E-01	9.09E-06
15.0	6.78E-01	8.86E-06

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	1.00E+00	mg/kg

Level 1 Parameters

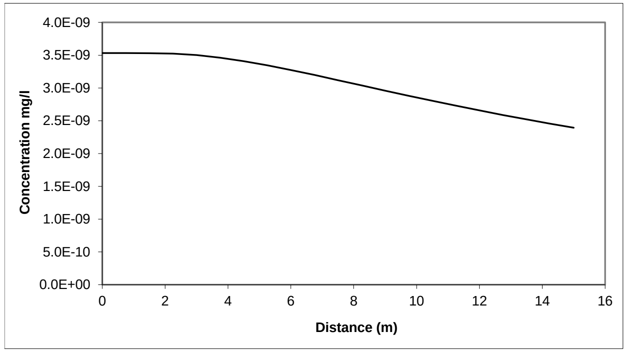
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	4.90E+03	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.67E+06	l/kg
Factor (partitioning between soil and water)		3.67E+06	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	2.72E-07	mg/l	No dilution or attenuation
Level 2	C	3.53E-09	mg/l	Dilution taken into account
Level 3	C	2.39E-09	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.53E-09
0.75	3.53E-09
1.50	3.53E-09
2.25	3.52E-09
3.00	3.50E-09
3.75	3.46E-09
4.50	3.41E-09
5.25	3.35E-09
6.00	3.27E-09
6.75	3.20E-09
7.50	3.12E-09
8.25	3.04E-09
9.00	2.96E-09
9.75	2.88E-09
10.50	2.80E-09
11.25	2.73E-09
12.00	2.66E-09
12.75	2.59E-09
13.50	2.52E-09
14.25	2.46E-09
15.00	2.39E-09

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		**Ali C16 - C21**		from Level 1
Target Concentration	C_T	**3.30E-01**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.40E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.67E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	5.65E+07	fraction
Decay rate used	λ	1.36E-108	d^{-1}
Rate of contaminant flow due to retardation	u	2.93E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.78E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.78E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.67E+06	l/kg

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

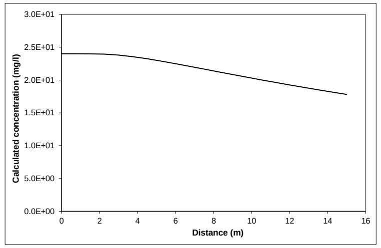
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run L

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.4E+01**
0.8	**2.40E+01**
1.5	**2.40E+01**
2.3	**2.39E+01**
3.0	**2.38E+01**
3.8	**2.36E+01**
4.5	**2.32E+01**
5.3	**2.29E+01**
6.0	**2.25E+01**
6.8	**2.21E+01**
7.5	**2.17E+01**
8.3	**2.13E+01**
9.0	**2.08E+01**
9.8	**2.04E+01**
10.5	**2.00E+01**
11.3	**1.96E+01**
12.0	**1.93E+01**
12.8	**1.89E+01**
13.5	**1.85E+01**
14.3	**1.82E+01**
15.0	**1.78E+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.

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

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:	**Former Chamber Bus Depot**			
Site Address:	**Church Square Bures CO8 5AB**			
Completed by:	**Rachel Foord**			
Date:	**20-Apr-23**		**Version:**	**Run M**
Contaminant	**Ali C16 - C21**			
Target Concentration (C_T)	**0.1**	**mg/l**	**Origin of C_T:**	**Based on WHO Guide values 0.3mg/l**

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 comparision 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		**Ali C16 - C21**	
Target concentration	C_T	**0.1**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porocity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porocity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	4.90E+03	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	6.38E-03	fraction	Reported value BHC at 4.00m 1.1%
Organic carbon partition coefficient	Koc	5.75E+08	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**3.67E+06**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**3.67E+05**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.1	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run M

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C16 - C21**		from Level 1
Target concentration	C_T	**0.1**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	Variable	Value	Unit	Source of parameter value	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data, 100% hardstanding drains**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**7.71E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		2.83E+07	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run M

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		**Ali C16 - C21**		from Level 1
Target Concentration	C_T	**0.1**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**3700**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	3.67E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	5.65E+07	fraction
Decay rate used	λ	1.23E-108	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	2.97E-08	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	1.01E-03	mg/l

Remedial Targets

Level 3 Remedial Target		**1.14E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.18E+07	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.67E+06	l/kg

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

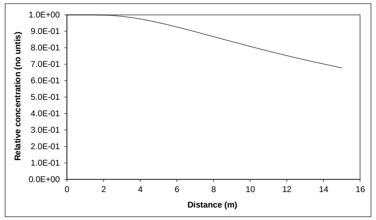
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run M

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	**1.0E+00**	**1.31E-05**
0.8	**1.00E+00**	**1.31E-05**
1.5	**1.00E+00**	**1.31E-05**
2.3	**9.98E-01**	**1.30E-05**
3.0	**9.91E-01**	**1.30E-05**
3.8	**9.80E-01**	**1.28E-05**
4.5	**9.65E-01**	**1.26E-05**
5.3	**9.47E-01**	**1.24E-05**
6.0	**9.27E-01**	**1.21E-05**
6.8	**9.05E-01**	**1.18E-05**
7.5	**8.83E-01**	**1.15E-05**
8.3	**8.60E-01**	**1.12E-05**
9.0	**8.38E-01**	**1.09E-05**
9.8	**8.16E-01**	**1.07E-05**
10.5	**7.94E-01**	**1.04E-05**
11.3	**7.73E-01**	**1.01E-05**
12.0	**7.52E-01**	**9.83E-06**
12.8	**7.33E-01**	**9.57E-06**
13.5	**7.14E-01**	**9.33E-06**
14.3	**6.95E-01**	**9.09E-06**
15.0	**6.78E-01**	**8.86E-06**

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	1.00E+00	mg/kg

Level 1 Parameters

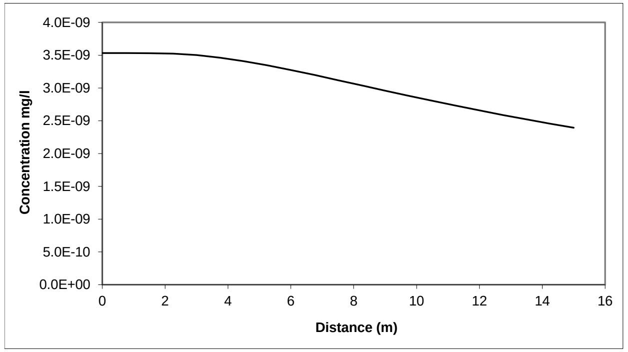
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	4.90E+03	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	3.67E+06	l/kg
Factor (partitioning between soil and water)		3.67E+06	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	2.72E-07	mg/l	No dilution or attenuation
Level 2	C	3.53E-09	mg/l	Dilution taken into account
Level 3	C	2.39E-09	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	3.53E-09
0.75	3.53E-09
1.50	3.53E-09
2.25	3.52E-09
3.00	3.50E-09
3.75	3.46E-09
4.50	3.41E-09
5.25	3.35E-09
6.00	3.27E-09
6.75	3.20E-09
7.50	3.12E-09
8.25	3.04E-09
9.00	2.96E-09
9.75	2.88E-09
10.50	2.80E-09
11.25	2.73E-09
12.00	2.66E-09
12.75	2.59E-09
13.50	2.52E-09
14.25	2.46E-09
15.00	2.39E-09

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant		Ali C16 - C21		from Level 1
Target Concentration	C_T	1.00E-01	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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
Initial contaminant concentration in groundwater at plume core	C_0	2.40E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	3.67E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	5.65E+07	fraction
Decay rate used	λ	1.36E-108	d^{-1}
Rate of contaminant flow due to retardation	u	2.93E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.78E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**1.35E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.78E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	6.38E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.67E+06	l/kg

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

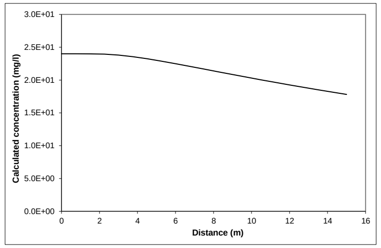
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run M

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Concentration**
	mg/l
0	**2.4E+01**
0.8	**2.40E+01**
1.5	**2.40E+01**
2.3	**2.39E+01**
3.0	**2.38E+01**
3.8	**2.36E+01**
4.5	**2.32E+01**
5.3	**2.29E+01**
6.0	**2.25E+01**
6.8	**2.21E+01**
7.5	**2.17E+01**
8.3	**2.13E+01**
9.0	**2.08E+01**
9.8	**2.04E+01**
10.5	**2.00E+01**
11.3	**1.96E+01**
12.0	**1.93E+01**
12.8	**1.89E+01**
13.5	**1.85E+01**
14.3	**1.82E+01**
15.0	**1.78E+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.

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

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: **Former Chamber Bus Depot**
Site Address: **Church Square Bures CO8 5AB**

Completed by: **Rachel Foord**
Date: **20-Apr-23** **Version:** **Run O**

Contaminant **Ali C16 - C21**
Target Concentration (C_T) **0.33** **mg/l** **Origin of C_T:** **Based on 1mg/l effective clean up**

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 comparision 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

Environment Agency

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		**Ali C16 - C21**	
Target concentration	**C_T**	**0.33**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	1.52E-01	fraction	Porocity calculator using reported WC of 7.7%
Air filled soil porosity	θa	1.40E-01	fraction	Porocity calculator using reported WC of 7.7%
Bulk density of soil zone material	ρ	1.97E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Henry's Law constant	H	4.90E+03	dimensionless	*Table 10-7 Generic Assessment Criteria LQM 2007*
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 soil)	foc	2.32E-03	fraction	Assuming 0.4%SOM
Organic carbon partition coefficient	Koc	5.75E+08	l/kg	*LQM/CIEH S4ULS 2015 Table 17-12*
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**	**1.34E+06**	**l/kg**	*Calculated 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.

Level 1 Remedial Target

Level 1 Remedial Target	**4.41E+05**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.33	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Ali C16 - C21**		from Level 1
Target concentration	C_T	**0.33**	**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 contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.50E-04	m/d	**Met Office rainfall data 100% hardstanding drains**	
Area of contaminant source	A	2.50E+01	m^2	**Estimated from site observations 5m by 5m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.00E+01	m	**Estimated from site observations**	
Saturated aquifer thickness	da	1.05E+01	m	**Based on measurement in BHG**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.38E+02	m/d	**Based on measurement in BHG**	
Hydraulic gradient of water table	i	1.80E-03	fraction	**Assessed from site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m	**Estimated from site**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.07E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**7.71E+01**		
Level 2 Remedial Target		**2.54E+01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration.**
		or		
		3.40E+07	**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)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	20-Apr-23
Version:	Run O

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	**Variable**	**Value**	**Unit**	**Source**
Contaminant		**Ali C16 - C21**		from Level 1
Target Concentration	C_T	**0.33**	mg/l	from Level 1
Dilution Factor	**DF**	**7.71E+01**		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	**Soil concentration as mg/kg**			
Enter soil concentration		**3700**	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	1.07E+00	m	from Level 2
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Estimated*
Hydraulic gradient	i	1.82E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.38E+02	m/d	from Level 2
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
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	1.34E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.500	m	*see options*
Transverse dispersivity	az	0.150	m	*see options*
Vertical dispersivity	ay	0.015	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	**Variable**		
Groundwater flow velocity	v	1.68E+00	m/d
Retardation factor	Rf	2.06E+07	fraction
Decay rate used	λ	3.37E-108	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.82E-03	fraction
Rate of contaminant flow due to retardation	u	8.16E-08	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	6.78E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.48E+00**	**fraction**
Calculated soil leachate concentration	Co	2.77E-03	mg/l

Remedial Targets

Level 3 Remedial Target		**3.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		5.01E+07	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**15**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**6.78E-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	foc	2.32E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	1.34E+06	l/kg

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

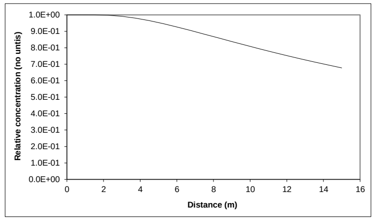
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-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 desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation 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.

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:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	########
Version:	Run O

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Relative concentration (No units)**	**Concentration mg/l**
0	**1.0E+00**	**3.59E-05**
0.8	**1.00E+00**	**3.59E-05**
1.5	**1.00E+00**	**3.59E-05**
2.3	**9.98E-01**	**3.58E-05**
3.0	**9.91E-01**	**3.56E-05**
3.8	**9.80E-01**	**3.52E-05**
4.5	**9.65E-01**	**3.47E-05**
5.3	**9.47E-01**	**3.40E-05**
6.0	**9.27E-01**	**3.33E-05**
6.8	**9.05E-01**	**3.25E-05**
7.5	**8.83E-01**	**3.17E-05**
8.3	**8.60E-01**	**3.09E-05**
9.0	**8.38E-01**	**3.01E-05**
9.8	**8.16E-01**	**2.93E-05**
10.5	**7.94E-01**	**2.85E-05**
11.3	**7.73E-01**	**2.78E-05**
12.0	**7.52E-01**	**2.70E-05**
12.8	**7.33E-01**	**2.63E-05**
13.5	**7.14E-01**	**2.56E-05**
14.3	**6.95E-01**	**2.50E-05**
15.0	**6.78E-01**	**2.44E-05**

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	1.00E+00	mg/kg

Level 1 Parameters

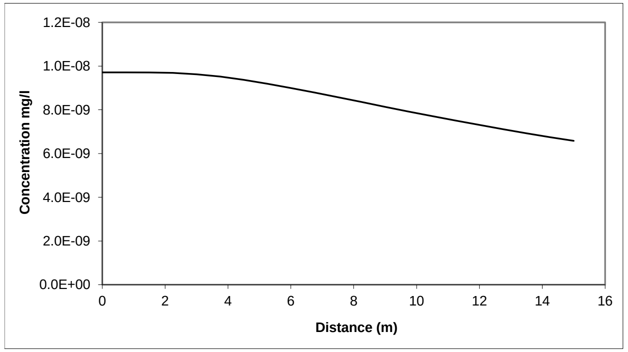
Water filled soil porosity	θ_W	1.52E-01	fraction
Air filled soil porosity	θa	1.40E-01	fraction
Bulk density	ρ	1.97E+00	g/cm^3
Henry's Law constant	H	4.90E+03	dimensionless
Soil water partition coefficient used in Level Assessment	Kd	1.34E+06	l/kg
Factor (partitioning between soil and water)		1.34E+06	dimensionless

Level 2 Parameters	**Dilution Factor**	DF	7.71E+01
Level 3 Parameters	**Attenuation factor (C_O/C_{ED})**	AF	1.48E+00

Predicted concentrations at compliance point

Level 1	C	7.49E-07	mg/l	No dilution or attenuation
Level 2	C	9.71E-09	mg/l	Dilution taken into account
Level 3	C	6.58E-09	mg/l	Dilution and attenuation taken into account

Predicted concentrations between source and compliance point - Level 3



Distance m	Concentration mg/l
0.00	9.71E-09
0.75	9.71E-09
1.50	9.71E-09
2.25	9.69E-09
3.00	9.63E-09
3.75	9.52E-09
4.50	9.37E-09
5.25	9.20E-09
6.00	9.00E-09
6.75	8.79E-09
7.50	8.57E-09
8.25	8.36E-09
9.00	8.14E-09
9.75	7.92E-09
10.50	7.71E-09
11.25	7.51E-09
12.00	7.31E-09
12.75	7.11E-09
13.50	6.93E-09
14.25	6.75E-09
15.00	6.58E-09

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant		**Ali C16 - C21**		from Level 1
Target Concentration	C_T	**3.30E-01**	mg/l	from Level 1

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

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

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**
Initial contaminant concentration in groundwater at plume core	C_0	2.40E+01	mg/l	*BHA Laboratory Test Result*
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 (perpendicular to flow)	Sz	5.00E+00	m	*Estimated*
Plume thickness at source	Sy	1.50E+00	m	*Estimated from observations on site*
Saturated aquifer thickness	da	1.05E+01	m	*Based on site measurement in BHG*
Bulk density of aquifer materials	ρ	2.31E+00	g/cm^3	BGS OR/15/065 Table Appendix 4
Effective porosity of aquifer	n	1.50E-01	fraction	*Assessed*
Hydraulic gradient	i	1.80E-03	fraction	*Calculated from site measurements*
Hydraulic conductivity of aquifer	K	1.38E+02	m/d	*Calculated from site data*
Distance to compliance point	x	1.50E+01	m	*Based on distance to site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.34E+06	l/kg	*see options*
Longitudinal dispersivity	ax	1.50E+00	m	*see options*
Transverse dispersivity	az	1.50E-01	m	*see options*
Vertical dispersivity	ay	1.50E-02	m	*see options*

Calculated Parameters

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.66E+00	m/d
Retardation factor	Rf	2.06E+07	fraction
Decay rate used	λ	3.75E-108	d^{-1}
Rate of contaminant flow due to retardation	u	8.05E-08	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.78E+01	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.35E+00**	

Remedial Targets

Remedial Target		**4.45E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**15**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.78E+01**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

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.

Select Method for deriving Partition Co-efficient (using pull down menu)

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	2.32E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+08	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	1.34E+06	l/kg

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

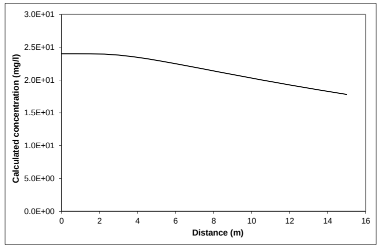
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	1.50E+00	1.23E+00	m
Transverse dispersivity	**az**	0.00E+00	1.50E-01	1.23E-01	m
Vertical dispersivity	**ay**	0.00E+00	1.50E-02	1.23E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

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



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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

Site being assessed:	Former Chamber Bus Depot
Completed by:	Rachel Foord
Date:	#######
Version:	Run O

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.4E+01
0.8	2.40E+01
1.5	2.40E+01
2.3	2.39E+01
3.0	2.38E+01
3.8	2.36E+01
4.5	2.32E+01
5.3	2.29E+01
6.0	2.25E+01
6.8	2.21E+01
7.5	2.17E+01
8.3	2.13E+01
9.0	2.08E+01
9.8	2.04E+01
10.5	2.00E+01
11.3	1.96E+01
12.0	1.93E+01
12.8	1.89E+01
13.5	1.85E+01
14.3	1.82E+01
15.0	1.78E+01

Compass Geotechnical
Geotechnical, Geoenvironmental and Civil Engineering Consultants

13 Willow Park, Upton Lane, Stoke Golding, Warwickshire, CV13 6EU
Tel: 01455 213311: Fax: 01455 213969
www.compassgeotechnical.co.uk