SOCIETY OF BROWNFIELD RISK ASSESSMENT

2018 Summer Workshop Outputs

Fine Tuning DQRAs for the Water Environment

PUBLICATION

This report is released by the Society of Brownfield Risk Assessment (SoBRA). It presents a written record of the discussions held during the Summer 2018 workshop. Attendees for each workshop are listed in the relevant section. Any views expressed in this report are not necessarily those of SoBRA or any of the contributing individuals or their employers.

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1 INTRODUCTION

The Society of Brownfield Risk Assessment (SoBRA) was established in December 2009 with the principal aim of promoting technical excellence in land contamination risk assessment in the United Kingdom (UK). As part of achieving this aim, SoBRA undertook to host regular conferences and workshops on technical subjects of interest to UK risk assessors and to facilitate and widen access to the dissemination of knowledge regarding land contamination risk assessment.

SoBRA held a one-day workshop in June 2018 entitled "*Fine Tuning DQRA's for the Water Environment*". The morning comprised a series of presentations from experts in the field as listed below.

- *"Legislative Update"* from Angela Haslam (Environment Agency)
- *"Understanding and Managing NAPL in Controlled Waters Risk Assessment"* from Ben Fretwell (Wood)*
- *"LNAPL Transmissivity – the API Workbook Overview & Limitations"* from Jonathan Larkin (AECOM)*
- *"Advanced Sediment and Soil Classification for DQRAs"* from Paul Nathanail (LQM)
- *"The Inclusion of Soakaway Modelling in Controlled Waters Risk Assessment"* from Bridget Plimmer (Golder Associates)*
- *"The Application of Natural Source Zone Depletion"* from Anwen Hughes (Golder Associates)
- *"Model Uncertainty in the Delivery of both RTM and ConSim Models"* from Vivien Dent (RSK) & Craig Hampton (Environment Agency)

Readers are referred to the SoBRA website for pdf copies of the expert speaker presentations.

The afternoon comprised workshop sessions on four themes:

- Common mistakes in the delivery of controlled waters (CW) Risk modelling and potential solutions;
- When to use biodegradation. How to demonstrate a consistent approach – lines of evidence, uncertainties and assumptions;
- When to use the API calculator, the input parameters and key lessons; and
- How to present uncertainty and sensitivity analysis in models.

This document provides a record of the discussions held in the four workshops. The conclusions and recommendations will be considered further by the SoBRA Executive Committee and used to shape future SoBRA reports, projects and events.

Those individuals who were registered to attend each workshop are presented in Appendix 1. The preparation material for each workshop (provided to participants in advance of the workshop day) is presented in Appendix 2.

2 COMMON MISTAKES IN CONTROLLED WATER RISK ASSESSMENTS AND POTENTIAL SOLUTIONS

2.1 Introduction

43 people attended this group, the majority from environmental and engineering consultancies, with nearly 30 companies represented from across the UK. The remainder were regulators from the Environment Agency, Natural Resources Wales, NHBC and consultants in corporate responsibility and compliance.

2.2 Objective

The objective was to identify common mistakes in controlled waters risk assessment and explore potential solutions.

2.3 Key Issues

Delegates were asked to identify their 'top 3' mistakes in controlled waters DQRA modelling and five main themes emerged (described in more detail below). Groups for each topic were assigned, and common mistakes and potential solutions were discussed in more detail.

1. Data acquisition	
Problem/Mistake	*Solutions*
• Limited site data • Over-reliance on published data • Mistakes in data collection, inappropriate data collection • Site staff or junior staff expected to do risk assessment • Lack of communication between staff on site and risk assessors • Data collected for geotechnical purposes not always appropriate for DQRA	• Communication within the team • Involve risk assessors in site investigation and design • Brief site staff, project manager and clients • Real time data dissemination between site staff and risk assessors • Support for early careers • Demonstrate value to client • Involved client in decision making (savings in remediation) • Regulator needs to push back on poor quality submissions

2. Conceptualisation	
Problem/Mistake	*Solutions*
• Source not connected with site history in sufficient detail • Lack of competency and experience • Over simplification • Repetitive, simple conceptual models • 'Stepping away from reality'	• Consciously record assumptions, along with clarity in assumptions • Person doing DQRA needs to have (competent) hydrogeological understanding • Maximise use of third-party data • Use of scoping calculations • Iterate as more data becomes available

3. Input parameters	
Problem/Mistake	*Solutions*
• Over use or misuse of literature values • Degradation used in all ranges • Parameter ranges inappropriate • FOC key but often no site data • Interdependent parameters not accounted for • Assumption that plume is stable • Degradation in all phases – is it ever justified? • Inadequate sensitivity analysis	• Clearer guidance on sensitivity analysis • Expansion and update of ConSim help pages • Clear guidance on which are the most sensitive parameters • Encourage calibration of models

4. Model Choice	
Problem/Mistake	*Solutions*
• Lack of understanding of model • Purpose of modelling is unclear	• Increase awareness of the difference between models • Increase understanding of how degradation and hydraulic gradient are used in particular • Be clear if purpose of the model is for validation or to derive remedial targets

5. Use of results	
Problem/Mistake	*Solutions*
As this was the last topic, only solutions were discussed	• Recognise that risk assessment is an iterative process • More pressure from industry and regulators that calibration and validation is required • Quantification of uncertainty and requirement for calibration with a defined percentage • 'Sanity check' • Communication with stakeholders at all stages • Better integration between risk assessment and remedial strategy/verification • Cost-benefit analysis • Involve regulators at an early stage

2.4 Conclusions

There was consensus between consultants, advisors and regulators. The key themes were:

- Communication. There was a sense that DQRA was a 'bolt on' to projects and more weight should be given to communicating the gains to be obtained from good DQRA when talking to clients; investing money now will save money in the future. Communication within teams was a common theme; a clear message that field staff, risk assessors and remedial engineers need to work more closely together.

- Key issue guidance. The group requested a 'couple of pages' on key issues, with the overall objective of influencing the client and clearly demonstrating where it was best to focus resources, including reference to degradation and hydraulic conductivity.

- 'Consciously logging assumptions' – risk assessors should emphasise the iterative nature of conceptualisation and modelling, being realistic and focusing future work.

- ‘Sanity check’; a lack of routine validation and calibration of models was recognised. This should be embedded in the risk assessment culture to ensure ‘common sense’ representation of the environment.
- Lack of consistency. Continue pushing back on poor quality reports. Backdrop of cuts to regulators - this needs to be pursued as an issue. Hope was expressed that SoBRA and NQMS will raise standards.

2.5 Recommendations

The group recommend that simple guidance on key steps in modelling is produced, including a summary of the sensitivity of common input parameters. The purpose of this is partly to encourage consistency across the sector, but predominantly with a view to communicating best practice and efficiencies to clients.

The group recommended that development of a competency framework for DQRA be explored with the aim of developing skills and encouraging consistency across the sector.

Practitioners are clearly relying on disparate sources of literature for input parameters, including key data for chemical behaviour and environmental quality standards. There is an opportunity for SoBRA to produce and maintain a definitive set of up to date literature-based values.

3 WHEN TO USE BIODEGRADATION? HOW TO DEMOSTRATE A CONSISTENT APPROACH – LINES OF EVIDENCE, UNCERTAINTIES AND ASSUMPTIONS

3.1 Introduction

The workshop attendees were asked to identify key questions associated with the application of biodegradation in risk assessment. Issues identified were:

a. The variation between the unsaturated and saturated zone biodegradation rates and the effect that natural spatial variation in lithology and contaminant distribution has on published biodegradation rates typically used in Detailed Quantitative Risk Assessments (DQRAs).

b. What are the best lines of evidence to use? The Environment Agency guidance on monitored natural attenuation (MNA) defines three lines of evidence that can be used to determine the viability of MNA as a management technique for a contaminated land site, or for residual contamination. However, which of these are essential, what is consistently presented, and how much data is needed to justify the use of biodegradation within a DQRA model? What are the new techniques which are coming into common use?

c. What would the regulator accept for lines of evidence for biodegradation, and how much site-specific data and model calibration are required to support the conclusions on MNA or remedial targets? Is it sufficient to apply literature values, and how do you choose them?

d. Is there a standard approach that could be applied to biodegradation sensitivity analysis, and uncertainty assessment?

e. When should you tick the box that assumes that all phases of contamination degrade? The greater majority of literature values on contaminant degradation tend to be the results of laboratory experiments using aqueous phases, rather than field studies. The petroleum hydrocarbons field studies are limited to relatively homogeneous media, and as such degradation rates, including those mediated by bacteria, may not reflect natural processes in other geological formations. Anecdotal evidence suggests that dissolved phase plumes may not develop down gradient of all Non-Aqueous Phase Liquid (NAPL) spills, and if this is the case should we assume that degradation does not impact the NAPL or should greater emphasis be placed on assessing this perhaps using the information discussed in ITRC 2009?

3.2 Objective

The objective was to identify when biodegradation can be used and what level of evidence is required to support its use.

3.3 Key Issues

A more in-depth discussion then occurred over two key issues:

3.3.1 When can biodegradation be used within risk assessment?

The short answer is when it can be properly justified, within the context of the purpose of the risk assessment, and in particular, the DQRA. The purpose of the risk assessment must be clearly stated, with different levels of evidence required in assessments for the purpose of remedial design over assessments for the purpose of risk characterisation. The depth of evidence required will vary between sites, and a pragmatic approach is acceptable. However, the use of rates to remove contaminant from a system are not justified where evidence is inconclusive (e.g. due to variability, limited sampling or poor-quality control), and/or biodegradation or abiotic decay decreases in contaminant mass are not proven. The Environment Agency (2000) MNA guidance identifies three lines of evidence:

Primary evidence: contaminant concentration and the concentration of any related degradation products. The relationship between contaminant concentration, spatial distribution and time can be key to proving biodegradation within the aquifer for MNA assessment.

Secondary evidence: concentrations of redox species that act as electron acceptors to facilitate bacterial metabolism, and concentrations of resulting reduced species. Measurements of dissolved gases, such as dissolved carbon dioxide, hydrogen sulphide and oxygen can be important. Increasing evidence shows that co-metabolism of various contaminants is also significant

Tertiary evidence: evidence of bacteria undertaking biodegradation, presence of bacteria species that may be able to reduce specific contaminants or facultative species such as methanogens. It could be argued that this is the point at which the potential for biodegradation at a site is actually proven. Methods to obtain evidence of bacterial metabolism include isotope analysis (generally considered inconclusive), biotraps and microcosm studies (may be representative of the biology within the well rather than within the aquifer), core microcosms (more representative of in-situ biology - but difficult to do with some aquifer materials), volatile fatty acid (VFA) analysis, phospholipid fatty acid analysis (PLFA; becoming cheaper and more widely available), and quantitative polymerase chain reaction (QPCR) and environmental DNA analysis to identify specific bacterial geni (new techniques being developed which will reduce costs).

As stated in the CL:AIRE 2017 Petroleum Hydrocarbon guidance, it is not necessary to undertake all of these to provide evidence that biodegradation is occurring, and professional judgement should be applied. The development of environmental VFA and DNA techniques has meant that Tertiary evidence is increasingly accessible in terms of price and reliability.

3.3.2 Should it be assumed that biodegradation happens in all phases?

The Remedial Targets Methodology (RTM) worksheet (Environment Agency, 2006) allows the user to select from two options to apply degradation rates to the contaminants, assuming that there is sufficient evidence from geochemical measurements to support the hypothesis.

"Apply degradation rates to dissolved substances only"; applicable where the degradation rate is obtained from laboratory studies of the substance in water; and

"Apply degradation rates to substances in all phases"; applicable where the degradation rate is observed from field observations.

The field observations can be from the site in question, previous studies, or the wider literature. Generally, field data incorporates both abiotic and biological degradation and there is no distinction between the two. One exception to this is when a particular decay sequence is observed that can only be obtained via biological degradation, such as those observed in chlorinated hydrocarbons.

Laboratory methods can estimate the proportions due to abiotic and biological degradation in a particular phase but do not replicate the role of the substrate and recharge. There is a large volume of published data available for bulk petroleum hydrocarbons and their associated contaminants. Less data is available for individual hydrocarbon fractions and emerging or more unusual contaminants. The CL:AIRE 2017 petroleum hydrocarbons document, and prior publications, recommend the use of indicator compounds to derive degradation rates for individual hydrocarbon fractions but field data is still relatively limited for British geology.

Regulator acceptance of field data calibrating plume degradation is generally strong, but collection of this data is limited due to the issues of siting down-gradient monitoring wells in the UK. SoBRA could look at collating study outcomes to help assess the relationship between geology, flow regime particularly in Chalk, degradation rate, NAPL plume length, and dissolved plume length across the UK.

There is increasing evidence that degradation occurs within source zones (ITRC, 2009; Golders 2016), and bacterial populations and associated biofilms have been demonstrated to use free phase material as a substrate for growth in oil well fields since the 1980s. Emulsions and globules are degraded within seawater. In the ground, the presence of smear zones within the capillary fringe can lead to variable oxygen saturation within a sediment facilitating degradation, and there is also the potential that pore spaces where pore throat diameters prevent hydrocarbon entry can act as reservoirs fuelling bacterial activity. Where field data is present there seems to be no justification in not pressing the all phase button, even where the degradation rate is derived from literature. However, literature values of field rates must be carefully selected, and that selection justified within the risk assessment.

3.4 Conclusions and Recommendations

It is essential when collecting and documenting lines of evidence that:

a. Parameters are measured in the field as accurately as possible and data such as impossible readings of dissolved oxygen (DO) and oxygen reduction potential (ORP) are explained and excluded from the analysis;
b. The impact of monitoring well construction such as screen length and materials are incorporated into the discussion of data;
c. The impact of well sampling methods is incorporated into the discussion of data;
d. Suitable background data on aquifer geochemistry is provided;
e. Tertiary biological evidence is presented where primary/secondary evidence is weak and poorly explained;
f. That the collection of biological samples is carried out in a way that is representative, enabling consultants to present consistent results (use of biotraps was cited as variable);
g. Evidence is presented in a consistent manner;
h. Sensitivity analysis is carried out in a consistent manner (it is a recommendation that SoBRA look at a working group on sensitivity analysis); and
i. All field data represents a snapshot in time, and the way in which conditions and biodegradation may change over a long period of time should be discussed (it is a recommendation that SoBRA also consider a working group on this issue).

The preferred evidence is biodegradation rates that are calibrated against a site-specific borehole array. Uncertainty can be off-set by sensitivity analysis, but it is reasonable to assume that if the conditions are suitable, degradation will occur in all phases.

4 WHEN TO USE THE API CALCULATOR

4.1 Introduction

The workshop was designed to open a discussion about the use of American Petroleum Institute's (API) transmissivity workbook, how best to use it, and what the common problems are when using it. Representatives of all career stages, from consultants, contractors and the Environment Agency were present. The workshop was an open discussion.

4.2 Objective

The objectives of the group were to discuss the API calculator, any issues that have been uncovered using it, and the main barriers that prevented it from being used. The workshop was orientated to be more exploratory than directly instructive. Other objectives were to discuss:

- Why is LNAPL removal carried out?
- Can the API tool be used to inform decision-making processes and conceptual site models?

4.3 Key Issues

The issue that dominated all others is the lack of useful data to feed into the API tool. There was a general agreement that collecting data for the transmissivity calculations is problematic. The main problem appears to be a disconnect between the required model data collection methodology (using interface probes) and the way the test is carried out by site operatives. One of the main problems is monitoring the groundwater response to the removal of LNAPL. Practical experience is important. A baildown test is a physical technique, and the more often it is undertaken the better the practitioner becomes. Bad data leads to uncertainty and a possible reticence about using transmissivity calculations. LNAPL thickness, while of limited scientific value, is much easier to record.

A number of views were put forward suggesting that the tool is currently of little use, because of the difficulties in collecting data that can be analysed. There was discussion about data filtering and the validity of measurements that had been collected, often at expense and effort.

The differences between LNAPL migration and mobility were discussed, with migration being understood to take place when sufficient driving head is present within the LNAPL body. This generally takes place only at the initial stage of a spill. However, the LNAPL plume may be internally mobile – and therefore recoverable to some extent. This is what is understood by the term 'mobile LNAPL'. Flux parameters were discussed in this context, but it was conceded that these provide a bulk measurement of the LNAPL's potential to move, and they are often not detailed enough to form a remediation strategy.

There was some discussion about equating LNAPL recovery with a reduction in risk: LNAPL recovery will result in a reduction in the timescale over which vapour and dissolved phase risks will persist but no solid conclusions were reached. The group noted that risks can exist from vapour and dissolved phase hydrocarbons derived from LNAPL, even when there is insufficient LNAPL to allow transmissivity testing, and when LNAPL is unable to enter wells. As such, LNAPL transmissivity assessment is often of more value to remediation practitioners than to risk assessors.

There was consensus about the importance of the geology, and how stratified geologies can have a large influence on transmissivity. The transmissivity was understood to be a 'snapshot' of how the LNAPL can move at that particular point in time, in that position in the well. LNAPL transmissivity is a line of evidence, and not a 'silver bullet'.

To characterise an LNAPL site, groundwater fluctuations need to be thoroughly understood, but commercial realities often preclude this level of detail.

Other methods of assessing LNAPL mobility were discussed, including combining particle size distribution and estimating LNAPL conductivity from those data. (Relative permeability should have been discussed at this point but was not).

There has been limited use of LNAPL transmissivity in the UK, but it is now more widely accepted by the Environment Agency. Regulatory acceptance is informed by risk. The concept of LNAPL transmissivity can also be used to explain to clients why large thicknesses of LNAPL may remain on site, but why they may pose no risk in terms of LNAPL migration.

A question was posed as to whether the presence of LNAPL represents an ongoing risk. It is not specifically mentioned under Part 2A of the Environmental Protection Act, (1990), though risk assessment would count it as an ongoing source. As ever, multiple lines of evidence are required. Regulation is the driver of remediation and will change over time as the science improves.

Transmissivity measurements can be used to inform the Conceptual Site Model (CSM) from which a calculation of risk can be derived. The CSM should also be continually updated with new data. However, this observation introduces a circular argument. With the problem of capturing data, if there is little data in the first instance that can be analysed, the CSM cannot be updated.

The concept of certified testers was put forward, but there would be an issue of mentoring. The major consensus was that there has been a lack of good baildown test data, partly due to the lack of experience and partly because only a small proportion of contaminated sites in the UK have wells that contain sufficient LNAPL thickness. In turn, there has been little to analyse with the API transmissivity calculator. This is further compounded by issues with LNAPL wells. For suitable data, these need to be developed and in continuity with formation LNAPL and for water level fluctuations to be understood (Larkin, 2018).

As a general point, there perhaps needs to be care taken when discussing LNAPL and related concepts. There have been numerous instances of what appear to be misunderstandings around terms and relations between different aspects of LNAPL movement in soil.

4.4 Conclusions and Recommendations

LNAPL is a poorly understood contaminant. The most appropriate method of measuring its recoverability – the transmissivity – is generally not used as effectively as it could be, due to the lack of valid data. Baildown tests have been, in the experience of those present, a poor source of useful information.

There is a requirement across the industry for better understanding about LNAPL mobility and for improved LNAPL data collection. This will allow interested parties to use the API tool, and to create CSMs for LNAPL that meaningfully represent site conditions.

5 HOW TO PRESENT UNCERTAINTY AND SENSITIVITY ANALYSIS IN MODELS

5.1 Introduction

Representatives from the industry included environmental consultancies, remediation contractors, the Environment Agency and a representative from the developer of the ConSim software, Golders Associates.

5.2 Objective

The objective was to consider key issues associated with uncertainty and sensitivity analysis when using the Environment Agency Remedial Targets Methodology model (RTM) and the Golders Associates CONSIM model (CONSIM).

5.3 Key Issues

The key issues and importance when dealing with uncertainty discussed during the workshop are detailed below:

1. Type of Uncertainty,
2. Use of field/laboratory data within models,
3. Model Choice,
4. Model Parameters, and
5. How to manage uncertainty.

5.3.1 Type of Uncertainty

There are two main types of uncertainty: Uncertainty within the model utilised, and Laboratory uncertainty.

- Model Uncertainty: if there is uncertainty of output following sensitivity analysis, model users must make a decision when choosing to accept or reject remedial targets. If all outcomes are the same following sensitivity analysis, then this is not so important, but if the remedial targets change following the sensitivity analysis, then this is very important.

- Queries were raised how best to express uncertainty within laboratory testing results, and how much this could influence a model, although it was generally agreed that site heterogeneity is likely to outweigh laboratory uncertainty.

5.3.2 Use of Laboratory Data

- The preference for using on-site laboratory measurements /in-situ parameters versus laboratory data was discussed e.g. use of water quality sondes / in-situ sensors.
- When discussing how best to interpret laboratory data, it was noted that for certain parameters reproducibility can be poor between laboratories e.g. due to the use of different analytical techniques/ preparation methods for organic analyses. Certain attendees have submitted aliquots of water samples to different laboratories and received differing results.
- There may be seasonal variability within data that can only become apparent with long term monitoring.
- The group was unsure how best to express uncertainty within laboratory results and were unsure how much these could influence model outputs.
- Consultants need to make a decision whether to accept / reject model outputs such as remedial targets and need to show pragmatism when putting forwards remedial targets for a site. The decision should take into consideration factors such as cost, remediation technology, laboratory limits of detection, and realistic and achievable remedial targets.

5.3.3 Model Choice

- The choice of model used is dependent on the Conceptual Site Model, level of accuracy required and stage of assessment: if complex sources of contamination / geology have been encountered on site, the complexity of model should increase e.g. the RTM/ CONSIM versus a site-specific model.
- While a more sophisticated model may reduce the risk/ uncertainty/remediation scope, in practice this is not always possible and likely to be dictated by the Client's budget and the development time frame. Consultants struggle to explain to clients the potential implications from regulators if they do not comply with legislation or recommendations.

5.3.4 Model Parameters

- Key parameters where site testing data is preferable over literature values include hydraulic conductivity, hydraulic gradient, contamination source information (e.g., width of plume).
- There is a difference between heterogeneity and natural variation within parameters, and a better understanding of the data is required when using CONSIM. However, careful consideration is still required when selecting input values to use in the RTM.
- Multiple lines of evidence are preferable when selecting values for use within a model.
- Site specific data is important, but there can be variability within data sets that may be best described using statistics / best case versus worst case scenarios.
- Uncertainty can be used to drive model refinement; undertaking this first can highlight key parameters that are critical to remediation and drive further site investigation.
- The group acknowledged that parameters affects each of the models in different ways, e.g. the RTM is sensitive to bulk density, the thickness of the mixing zone, distance to receptor.
- There can be multiple sources, potentially merging down gradient of the source.

5.3.5 How to Manage Uncertainty

- CLR 11 (Defra & Environment Agency, 2004) requires information to be reviewed with the following criteria in mind: Relevant, Sufficient, Reliable, Transparent.
- The iterative approach to DQRA and modelling needs to be acknowledged earlier within reports.
- The group advocated undertaking the sensitivity analysis first, which requires formalising within guidance.
- While model results can produce a spread of outcomes, the model needs to best describe the conditions encountered on site.
- The group advocated the use of probability density functions (Environment Agency, 2001c).
- Model projections need to be appropriately validated e.g. installation of validation wells, models calibrated using site specific data where possible.

- An uncertainty register or table could be provided within the report to highlight the uncertainty associated with each parameter, and how critical this is to the model output/ remedial targets.
- The pre-engagement of regulators at an earlier stage, to discuss the approach and uncertainty within a DQRA, may help to manage client expectations and enable faster regulatory acceptance of remedial targets.
- Better communication is required between consultants and clients. Consultants need to be more explicit when discussing the potential uncertainties and assumptions within models, and their potential impact on remedial target values. This may impact insurance and liability for the consultancy undertaking a DQRA, and lead to conflict with remediation contractors and/ or the developer.

5.4 Conclusions and Recommendations

- The group agreed that a degree of pragmatism is needed when interpreting model results.
- The inclusion of field or laboratory data is preferable over literature reference values, as this will help to validate the model results.
- Uncertainty can be used to drive model refinement: this will identify which parameters are critical, and drive further investigation, in turn providing a reality check for model outputs.
- DQRA reports need to be re-organised, placing the sensitivity analysis towards the front of the report to emphasise the effect of changing key parameters within the model on remedial targets. Parameter tables should be included, demonstrating a best, worst case and middle range. A standard DQRA report template could be developed by SoBRA.

5.5 Recommendations

The group agreed that SoBRA should develop a one-page sheet summarising uncertainty to place within DQRA report. A standard DQRA report template, including an uncertainty register and placing the uncertainty analysis earlier within the document, could be offered by SoBRA.

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APPENDIX 1

Workshop Participants

SoBRA
The Society of Brownfield Risk Assessment

WORKSHOP 1: The top 10 mistakes in the delivery of CW Risk Modelling

Facilitator and rapporteur:	Ben Fretwell, Wood, Theresa Cory, EA, Beth Davies, NRW
Name	**Company**
Hugh Addlesee	EnviroCentre Limited
Stephanie Allcock	PJA Engineering
Christiano Ascolani	Capita
Oliver Baldock	Ashfield Solutions Ltd
Rebecca Beddard	Mayer Environmental
Sophie Bismire	Arup
Neil Brown	SOCOTEC
Aaron Cousins	N/A
Kirsty Darby	Environment Agency
Amanda David	Lister Geotechnical Consultants
Jesse Davies	Ramboll
Daniel Fisher	Adeptus
Nick Frost	Terraconsult
Peter George	Go Contaminated Land Solutions
Victoria Griffin	Waterco Ltd
Angela Haslam	Environment Agency
Richard Holloway	Ridge & Partners LLP
Paul Huteson	Delta Simons
Adrian King	Omnia Consulting
Madeleine King	MLM Group Ltd
Mark Knight	MDK Environmental
Matt Lennard	NHBC
Thomas Levick	Amey
Jenny Lightfoot	Arup
Roisin Lindsay	Arup
Lindsay Liness	MLM Group
Martin Lucass	WSP
Ross Maguire	WSP
Trevor Montague	Geosyntec Consultants
Kimberley Neville	CGL
Andreas Neymeyer	Curtins
Sophie Passmore	Ramboll
Haf Peskett	NRW
Mike Plimmer	GEA
Harry Preston	Brownfield First
Paul Quimby	LK Group
Rob Reuter	Wardell Armstrong
Diane Robson	GEMCO
Ken Scally	Chemtest
Keisha Smith	WSP
Mike Summersgill	SEnSE Associates LLP
Chris Taylor	National Grid
Caroline Walker	Wood
Leon Warrington	Hydrock
Martin Weil	Landscience
Tom Wickens	Environment Agency

WORKSHOP 2: When can I use biodegradation? How can I demonstrate its acceptance for inclusion in a consistent approach?

Facilitator and rapporteur:	**Simon Firth Rachel Dewhurst**
Name	**Company**
Sarah Bannon	Ramboll
Gareth Barns	WYG
Chris Betts	Hydrogeo Limited
Lucy Burns	Advisian
Alison Carruthers	Mott MacDonald
James Cooper	Mayer Environmental
Joanne Fitton	NRW
Katie Gamlin	WSP
Mike Gennaro	Delta Simons
Ben Greenfield	Waterman
Alex Grimmer	BC of King's Lynn & West Norfolk
Nicholas Hills	Peter Brett Associates
Anwen Hughes	Golder Associates
Adam Janman	Environment Agency
Tim Mitchell	Omnia
Tom Parker	Argentum Fox
Emma Peace	Aecom
Dave Rutherford	Enfield Council
Keith Spence	Environment Agency
Jane Swift	Chemtest
Jane Taylor	Listers Geotechnical Consultants
Elizabeth Waterfall	Stantec

WORKSHOP 3: When to use the API Calculator

Facilitator and rapporteur:	Jonathan Larkin, Aecom. David Holmes, Ecologia
Name	**Company**
Vanessa Bell	Geo2
Sonia Devons	ERM
Andrew Fellows	Atkins Ltd
James Haillier	Landscience
Chris Hitches	Hydrock
Anna Hitchmough	RSK
Ana Jimenez	WSP
Ben Jones	SLR Consulting
Wojtek Koryczan	Environment Agency
Alex Lee	WSP
Tommy Lowden	Environment Agency
Barry Mitcheson	Wood
Nick Roe	Geosyntec Consultants
Ben Thomas	Smith Grant LLP
Anil Waduge	Environment Agency
Geraint Williams	SoBRA

WORKSHOP 4: How to present uncertainty and sensitivity analysis in our models and provide recommendations

Facilitator and rapporteur:	**Craig Hampton, Environment Agency. Emma Khadun, REC**
Name	**Company**
John Andrews	RSK
Susie Bateson	Environment Agency
David Brooks	Sirius Geotechnical
Cathy Cussell	RSK
John Davys	Environment Agency
Kari Dennis	Rodgers Leask
Vivian Dent	RSK
Olayinka Ekundayo	LB of Brent
David Jackson	Delta Simons
Robert Jiagge	ST Consulting
Themis Kantara	Environment Agency
Laura Legate	Geo-Environmental Services Ltd
Matthew May	Sweco
Kirsten Mills	Delta Simons
Paul Nathanail	LQM
Jane Oakeshott	ERM
Bridget Plimmer	Golder Associates
David Schofield	Ramboll
Adam Wilson	Geo2

APPENDIX 2

Workshop Preparation Material

Workshop Information Sheet: Group 1: Common pitfalls in delivery of CW-DQRAs

Facilitators: Theresa Cory, Environment Agency & Ben Fretwell, Wood

Rapporteur: Beth Davies, Natural Resources Wales

Background: This workshop will look at the key issues associated with the main pitfalls presented in cw-DQRA modelling. Delegates will be asked to consider a wide range of issues to identify those representing accepted scientific understanding and/or good practice, and those which require further work to extend, improve or clarify current understanding or practice.

Output: It is anticipated that each of the workshops will provide a shortlist of 4 to 8 priority issues. The groups will strive to reach a level of agreement on these issues. It is intended that all outcomes from the day will be collated into a published report which can be used to support decision-making within the brownfield land risk assessment community.

Workshop Structure:

Introduction (approx. 10mins)	Summary of the issues, key literature sources and examples of credible risk assessment principles or methodologies that are accepted by the broad risk assessment community.
Identifying issues and selecting key areas for discussion (approx. 20mins)	Identification of the main areas of concern, priorities, barriers and uncertainties, including any that cut across more than one workshop theme. Please bring ideas for discussion topics along - what do you feel are the key issues? The workshops are intended to be driven by the whole group not just the facilitators.
Group Discussion (approx. 1hr)	Some key issues for discussion are likely to include: • Which model? • Input parameters • Environmental Assessment Limits • CSM – receptors & SPLs
Summarise discussion (Approx. 15mins)	Summarise agreed points for input into the workshop report and identify a few key points for feedback to other delegates.

Key References: The links below identify a few key resources/papers on the discussion topic. Familiarity with these would aid discussion on the day. Additionally, if you are aware of other relevant papers please feel free to bring them along, with a short summary on the day.

- CL:AIRE LNAPL An Illustrated Handbook of LNAPL Transport and Fate in the Subsurface. CL:AIRE 2014.https://www.claire.co.uk/home/news/20-lnapl-illustrated-handbook-is-now-available
- Environment Agency, 2006. Remedial targets methodology: hydrogeological risk assessment for land contamination. Bristol: Environment Agency. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/314317/geho0706bleq-e-e.pdf
- Environment Agency, 2001. Guidance on assigning values to uncertain parameters in subsurface rate and transport models. National Groundwater and Contaminated Land Centre Report NC/99/38/3. Solihull: National Groundwater and Contaminated Land Centre. Available from: https://www.gov.uk/government/publications/guidance-on-assigning-values-to-uncertain-parameters-in-subsurface-contaminant-fate-and-transport-modelling

Workshop Information Sheet: Group 2: When to use Biodegradation in CW-DQRA.

Facilitator: Simon Firth (Firth Consultants Ltd)
Rapporteur: Rachel Dewhurst (Stantec)

Background: This workshop will look at the key issues associated with the inclusion of biodegradation in CW-DQRA modelling. Delegates will be asked to consider a wide range of issues to identify those representing accepted scientific understanding and/or good practice, and those which require further work to extend, improve or clarify current understanding or practice.

Output: It is anticipated that each of the workshops will provide a shortlist of 4 to 8 priority issues. The groups will strive to reach a level of agreement on these issues. It is intended that all outcomes from the day will be collated into a published report which can be used to support decision-making within the brownfield land risk assessment community.

Workshop Structure:

Introduction (approx. 10mins)	Summary of the issues, key literature sources and examples of credible risk assessment principles or methodologies that are accepted by the broad risk assessment community.
Identifying issues and selecting key areas for discussion (approx. 20mins)	Identification of the main areas of concern, priorities, barriers and uncertainties, including any that cut across more than one workshop theme. Please bring ideas for discussion topics along - what do you feel are the key issues? The workshops are intended to be driven by the whole group not just the facilitators.
Group Discussion (approx. 1hr)	Some key issues for discussion are likely to include: • Unsaturated & Saturated Zone • Biodegradation in all phases or dissolved phase only? • Redox conditions & Lines of evidence
Summarise discussion (Approx. 15mins)	Summarise agreed points for input into the workshop report and identify a few key points for feedback to other delegates.

Key References: The links below identify a few key resources/papers on the discussion topic. Familiarity with these would aid discussion on the day. Additionally, if you are aware of other relevant papers please feel free to bring them along, with a short summary on the day.

- CL:AIRE LNAPL An Illustrated Handbook of LNAPL Transport and Fate in the Subsurface. CL:AIRE 2014.https://www.claire.co.uk/home/news/20-lnapl-illustrated-handbook-is-now-available
- Environment Agency, 2006. Remedial targets methodology: hydrogeological risk assessment for land contamination. Bristol: Environment Agency. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/314317/geho0706bleq-e-e.pdf
- Environment Agency (2000) *Guidance on the Assessment & Monitoring of Natural Attenuation of Contaminants in Groundwater*. R&D Publication 95. http://webarchive.nationalarchives.gov.uk/20140328084622/https://publications.environment-agency.gov.uk/ms/6WGI4
- ITRC. 2009. *Evaluating Natural Source Zone Depletion at Sites with LNAPL*. Washington, DC: Interstate Technology and Regulatory Council. https://www.itrcweb.org/guidancedocuments/lnapl-1.pdf

Workshop Information Sheet: Group 3: When to use the API Calculator

Facilitator: Jonathan Larkin, Aecom
Rapporteur: David Holmes, Ecologia

Background: This workshop will look at the key issues associated with the API Calculator. Delegates will be asked to consider a wide range of issues to identify those representing accepted scientific understanding and/or good practice, and those which require further work to extend, improve or clarify current understanding or practice.

Output: It is anticipated that each of the workshops will provide a shortlist of 4 to 8 priority issues. The groups will strive to reach a level of agreement on these issues. It is intended that all outcomes from the day will be collated into a published report which can be used to support decision-making within the brownfield land risk assessment community.

Workshop Structure:

Introduction (approx. 10mins)	Summary of the issues, key literature sources and examples of credible risk assessment principles or methodologies that are accepted by the broad risk assessment community.
Identifying issues and selecting key areas for discussion (approx. 20mins)	Identification of the main areas of concern, priorities, barriers and uncertainties, including any that cut across more than one workshop theme. Please bring ideas for discussion topics along - what do you feel are the key issues? The workshops are intended to be driven by the whole group not just the facilitators.
Group Discussion (approx. 1hr)	Some key issues for discussion are likely to include: • When to use the API Calculator • When not to use the Calculator • Limitations and practical difficulties
Summarise discussion (Approx. 15mins)	Summarise agreed points for input into the workshop report and identify a few key points for feedback to other delegates.

Key References: The links below identify a few key resources/papers on the discussion topic. Familiarity with these would aid discussion on the day. Additionally, if you are aware of other relevant papers please feel free to bring them along, with a short summary on the day.

- ASTM Standard Guide for Estimation of LNAPL Transmissivity
- Charbeneau, R.J., Kirkman, A., Rangaramanujam, M., 2016. API LNAPL Transmissivity Workbook: a Tool for Baildown Test Analysis - User Guide. American Petroleum Institute. API Publication 4762, April 2016. http://www.api.org/oil-and-natural-gas/environment/clean-water/ground-water/lnapl/transmissivity-workbook
- Beckett, G.D. and Huntley, D., 2015. LNAPL transmissivity: a twisted parameter. *Groundwater Monitoring & Remediation*, *35*(3), pp.20-24.
- Interstate Technology Regulatory Council ITRC LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies (https://lnapl-3.itrcweb.org/)

Workshop Information Sheet: Group 4: Uncertainty & Sensitivity analysis

Facilitator: Craig Hampton, Environment Agency
Rapporteur: Emma Khadun, REC

Background: This workshop will look at the key issues associated with uncertainty and sensitivity analysis. Delegates will be asked to consider a wide range of issues to identify those representing accepted scientific understanding and/or good practice, and those which require further work to extend, improve or clarify current understanding or practice.

Output: It is anticipated that each of the workshops will provide a shortlist of 4 to 8 priority issues. The groups will strive to reach a level of agreement on these issues. It is intended that all outcomes from the day will be collated into a published report which can be used to support decision-making within the brownfield land risk assessment community.

Workshop Structure:

Introduction (approx. 10mins)	Summary of the issues, key literature sources and examples of credible risk assessment principles or methodologies that are accepted by the broad risk assessment community.
Identifying issues and selecting key areas for discussion (approx. 20mins)	Identification of the main areas of concern, priorities, barriers and uncertainties, including any that cut across more than one workshop theme. Please bring ideas for discussion topics along - what do you feel are the key issues? The workshops are intended to be driven by the whole group not just the facilitators.
Group Discussion (approx. 1hr)	Some key issues for discussion are likely to include: • How to manage uncertainty • Field/lab data • CSM • Model input parameters
Summarise discussion (Approx. 15mins)	Summarise agreed points for input into the workshop report and identify a few key points for feedback to other delegates.

Key References: The links below identify a few key resources/papers on the discussion topic. Familiarity with these would aid discussion on the day. Additionally, if you are aware of other relevant papers please feel free to bring them along, with a short summary on the day.

- Environment Agency 2000. Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface National Groundwater & Contaminated Land Centre report NC/99/38/2 http://webarchive.nationalarchives.gov.uk/20140328084622/http://publications.environment-agency.gov.uk/pdf/SCHO0701BITR-e-e.pdf
- Environment Agency 2001. Guidance on the Assessment and Interrogation of Subsurface Analytical Contaminant Fate and Transport Models National Groundwater & Contaminated Land Centre report NC/99/38/1 https://www.gov.uk/government/publications/guidance-on-the-assessment-and-interrogation-of-subsurface-analytical-contaminant-fate-and-transport-models
- Environment Agency 2008. Guidance on assigning values to uncertain parameters in subsurface contaminant fate and transport modelling https://www.gov.uk/government/publications/guidance-on-assigning-values-to-uncertain-parameters-in-subsurface-contaminant-fate-and-transport-modelling