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Model Procedures for the Management of Land Contamination

Contaminated Land Report 11

defra
Department for Environment Food and Rural Affairs

Environment Agency

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Statement of use

The Model Procedures for the Management of Land Contamination provides the technical framework for structured decision making about land contamination. They encourage the formalisation of outputs from the process in the form of written records that contain details of specific project objectives, decisions and assumptions, as well as recommendations and other specific outputs. The Model Procedures are intended to assist all those involved with, or interested in risk management of land affected by contamination.

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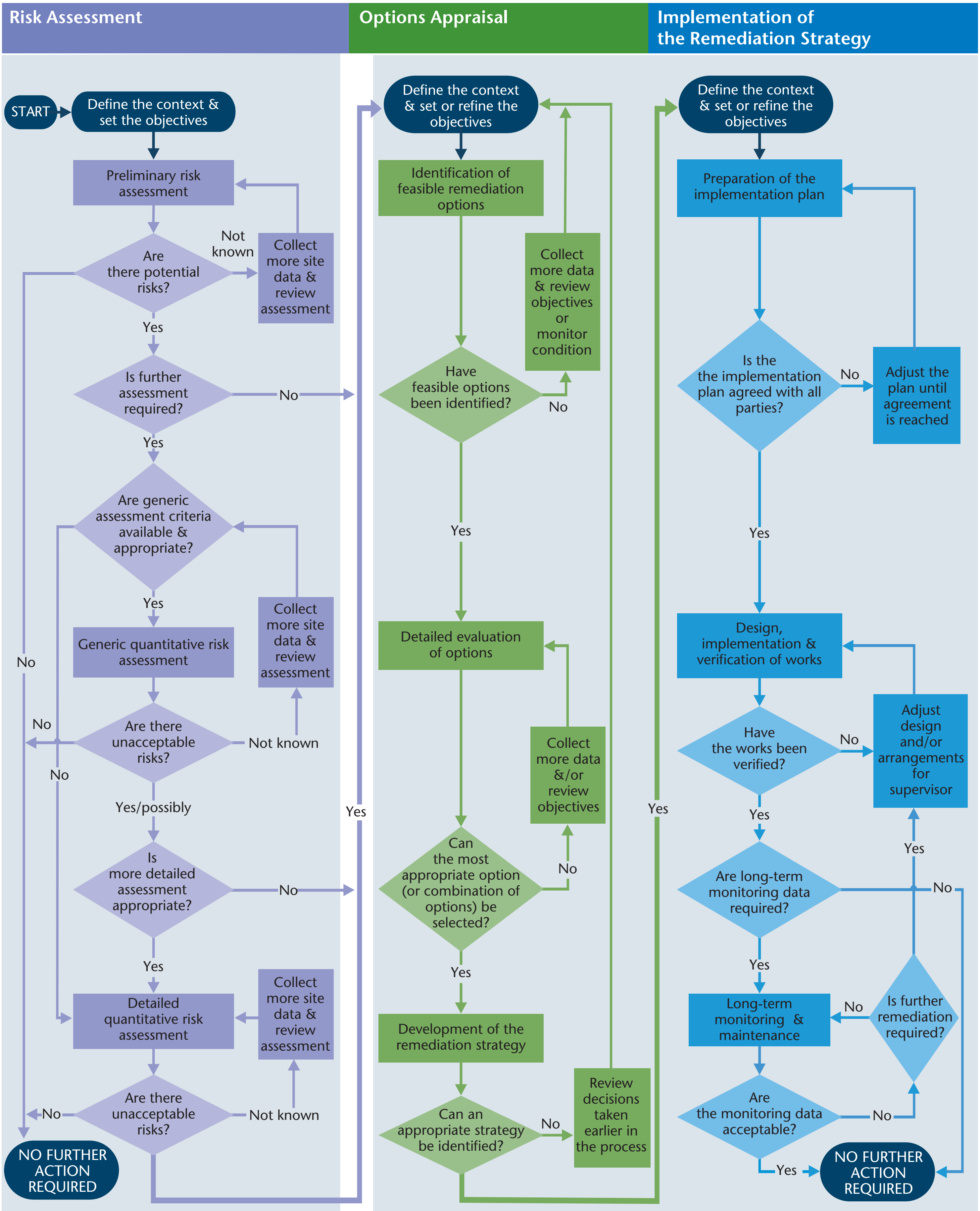
Figure 1 **The process of managing land contamination**



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Contents

Part 1 – Procedures

1

Acknowledgements

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The project was guided by a Steering Group that comprised of representatives from:

- Department for Environment, Food and Rural Affairs (Defra)
- Office of the Deputy Prime Minister
- Environment & Heritage Service, Northern Ireland
- Welsh Assembly Government
- Environment Agency
- Scottish Environment Protection Agency
- Chartered Institute of Environmental Health
- Welsh Development Agency

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Foreword

Like most industrial societies, we have a considerable legacy of land affected by contamination, often arising from past land use but also from some natural or diffuse sources. Where land has been affected by contamination it may present a risk to a range of receptors including humans, ecosystems, water quality, and property including crops and animals. Current and future use of the land may be adversely affected. Moreover, such potential risks, and uncertainty regarding risks, may inhibit the development or redevelopment of land, and in some cases contribute to long-term dereliction and increasing pressure to develop greenfield land.

The Model Procedures for the Management of Land Contamination, CLR 11, have been developed to provide the technical framework for applying a risk management process when dealing with land affected by contamination. The process involves identifying, making decisions on, and taking appropriate action to deal with, land contamination in a way that is consistent with government policies and legislation within the UK. This document is consistent with the approach presented within the "Guidelines for Environmental Risk Assessment and Management" published by the Department of the Environment, Transport and the Regions, the Environment Agency and the Institute for Environment and Health (2000). The publication of the risk management framework within this Contaminated Land Report fulfils one of the recommendations made in the Urban Task Force Report (1999).

The technical approach presented in the Model Procedures is designed to be applicable to a range of non-regulatory and regulatory contexts. These include

(i) Development or redevelopment of land under the planning regime;
(ii) Regulatory intervention under Part IIA of the Environment Protection Act 1990 or Part III of the Waste & Contaminated Land (Northern Ireland) Order 1997;
(iii) Voluntary investigation and remediation; and
(iv) Managing potential liabilities of those responsible for individual sites or a portfolio of sites.

These Model Procedures are intended to assist all those involved in dealing with land contamination, including landowners, developers, professional advisors, regulatory bodies and financial service providers. They are intended to improve procedural understanding of a risk-based approach to land contamination and provide a consistent framework for decision making. This in turn should encourage the sharing of knowledge and good practice amongst professionals and others.

Andrew Skinner, Director of Environment Protection

1

Overview of Model Procedures

The Model Procedures for the Management of Land Contamination are intended to provide the technical framework for structured decision-making about land contamination. The basic process can be adapted to apply in a range of regulatory and management contexts, subject to any specific constraints arising from these contexts. The Model Procedures are intended to assist all those involved in "managing" the land – in particular landowners, developers, industry, professional advisers, financial service providers, planners and regulators.

1.1 Understanding land contamination

Land contamination in its broadest sense describes a general spectrum of site and soil conditions. It can include areas with elevated levels of naturally occurring substances, as well as specific sites that have been occupied by former industrial uses, which may have left a legacy of contamination from operational activities or from waste disposal. It can also include areas of land in which substances are present as a result of direct or indirect events, such as accidents, spillages, aerial deposition or migration.

In general terms these circumstances can be described as "**land affected by contamination**". However, for any individual site the land manager or other interested person faces two questions:

- Does the contamination matter? and, if so
- What needs to be done about it?

The specific context of past contamination

The answers to both the questions above depend to some extent on when the contamination happened. For "new" contamination, the accepted principle is that deterioration of the environment needs to be avoided. This principle underlies the approach in regimes aimed at controlling potentially polluting activities, such as Pollution Prevention and Control (PPC). For example, the PPC regime has enforcement mechanisms to deal with cases in which land contamination is caused as a result of a breach in permit conditions. In such circumstances, the land should be restored to a satisfactory state – taken as the state before issuing the permit.

However, Government policy recognises that when dealing with past contamination, the opportunity to maintain a clean environment has already passed [1]. In deciding whether contamination matters, the amount, or concentration, of any contaminants present is always going to be a significant factor, but it does not provide the whole answer. It is also necessary to consider to what extent the substances present may harm human health or the wider environment, including damage to property such as buildings. In short, what risk, if any, is caused by contaminants, and is that **risk** unacceptable?

This need to make judgements about the degree of risk also applies to deciding what to do about the contamination. Technical obstacles as well as potentially large costs mean that it is often neither feasible nor realistic to think in terms of total clean-up of past damage. Instead, the goal is to find solutions that identify and deal with risks from contamination in a sustainable way [2].

The overall approach in dealing with past land contamination is therefore one of **risk management** – implying "all the processes involved in identifying, assessing and judging risks, taking actions to mitigate or anticipate them, and monitoring and reviewing progress" [3].

1.2 Managing risks from land contamination

What do we mean by risk?

The term risk is widely used in different contexts and circumstances, often with differing definitions. In Government publications about the environment [4], it has been given the following standard definition:

> *Risk is a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.*

This is the definition used in the Model Procedures, in the specific context of risks to health and the environment from land contamination.

The idea of the "pollutant linkage"

In the context of land contamination, there are three essential elements to any risk:

- A **contaminant** – a substance that is in, on or under the land and has the potential to cause harm or to cause pollution of **controlled waters**;
- A **receptor** – in general terms, something that could be adversely affected by a contaminant, such as people, an ecological system, property, or a water body; and
- A **pathway** – a route or means by which a receptor can be exposed to, or affected by, a contaminant.

Each of these elements can exist independently, but they create a risk only where they are linked together, so that a particular contaminant affects a particular receptor through a particular pathway. This kind of linked combination of contaminant–pathway–receptor is described as a **pollutant linkage**.

On any individual site, there may be only a single pollutant linkage or there may be several. Different pollutant linkages may be related, for example, the same contaminant may be linked to two or more distinct types of receptor by different pathways, or different contaminants and/or pathways may affect the same receptor. Not all receptors will be relevant in every context, and new pollutant linkages may be created by changes over time. Each pollutant linkage needs to be separately identified, understood and dealt with if appropriate.

Different site circumstances

The nature and level of risk are defined in large part by the particular condition and circumstances of any individual piece of land. The details of the use of the land itself, as well as surrounding land, determine whether particular receptors and pathways are present and, if they are, the extent to which they might potentially be affected by contamination. The environmental setting of the land, for example, the surrounding and underlying water environment, on-site and nearby ecosystems – are critical in the same way.

Other characteristics of the site also affect the nature and level of risk in any case. For example, the nature of the soil, the local climate and the underlying geology and hydrogeology all affect the risk presented by contamination.

Taking these factors together, the same concentration of a contaminant can have widely differing implications in different circumstances. **Risk assessment** allows this to be considered in a structured way so that appropriate and cost effective decisions are taken.

Deciding whether risk matters

Without a pollutant linkage, there is not a risk – even if a contaminant is present. But even where there is a pollutant linkage, and therefore some measure of risk, the question still needs to be asked as to whether the level of risk justifies **remediation**.

The answer again will depend on the context. For example, Government policy for dealing with past land contamination focuses on taking action where there are "unacceptable risks to human health and the environment" in relation to the use of the land and its environmental setting – the "suitable for use approach" [1]. This is carried forward into the definition of contaminated land under the regulatory regime in Part IIA of the Environmental Protection Act (EPA)1990 which considers risk in relation to the *current use* of the land and defined receptors. In planning and development control, the aim is to ensure that there are no unacceptable risks to either the receptors relevant to Part IIA or to others that may be covered by other regimes, but again taking into account the use of the land – in this case the proposed *new* use [5].

The question of whether risk is unacceptable in any particular case involves not only scientific and technical assessments of the particular circumstances (what is the level of risk represented by the circumstances of the site?), but also appropriate criteria to judge the risk (exactly what risk would be unacceptable?). The acceptability or significance of risk, including socio-economic aspects, is considered in general terms in the *Guidelines for Environmental Risk Assessment and Management* [4]. Decision-makers need to establish appropriate criteria for use in the specific context of land contamination. This is discussed in more detail in Chapter 2.

Uncertainty

In some cases, assessing land contamination involves direct observation of the effects or consequences of the existence of a hazard. This could take the form of visible pollutants leaching into water, or the observation of morbidity or death in livestock or crops. However, in very many cases, risk assessments will have to be based on a prediction of the risk. This relies on an understanding of how risks might arise, the characteristics of the site as determined through sampling, analysis and other investigations, and the use of models or other tools to estimate risk. All of these introduce **uncertainty**, as understanding of the risks may be incomplete, modelling may produce an imperfect representation of the real world, and sampling, analysis and other investigations may not provide an accurate reflection of the true or relevant characteristics of the site.

Risk-based decision making offers the opportunity to formalise the management of these different uncertainties. Statistical techniques can frequently be used to evaluate the scale of uncertainties, and sensitivity analysis used within risk assessment can allow evaluation of the potential significance of inherent uncertainties in the process to any final decision. In some cases, further information can be collected, and the calculations refined to reduce the levels of uncertainty.

Costs and benefits

At several stages of the risk management process, judgements have to be made about the relative costs and benefits of particular courses of action or decisions. This “cost–benefit analysis” is an inherent part of the management of environmental risks in a sustainable way, and is a formal component of particular stages of regulatory regimes. It allows for the structured and transparent balance of the costs (usually, but not always, in financial terms) against benefits, which can be wide-ranging depending on the context – for example, enhanced health and environmental protection, increased commercial confidence in the condition of the land or simply greater certainty in ultimate decision making.

The scope and particular criteria for any cost–benefit analysis will depend on the context.

For example:

- A purchaser may decide to buy land on the basis of a preliminary risk assessment alone (i.e., without any intrusive investigation and detailed risk assessment), provided he or she is confident that any contamination present can be addressed using appropriate measures, and the acquisition brings wider commercial benefits;
- A regulator may consider that very **detailed site investigation** and risk assessment are necessary because the nature of the contaminants, and gravity of potential effects, means that a failure to properly characterise the site and estimate the risks would result in unacceptable consequences;
- A developer may decide to use a remediation option that will bring a site up to a standard higher than is strictly necessary to protect health and the environment given the immediate proposed use of the land, if this produces wider benefits in terms of flexibility in land use over the long term and increased market value.

Such considerations should not challenge the basic technical structure of the risk management process. However, they strongly influence the way in which it is put into practice – they can determine the level of detailed work carried out at any particular stage, the speed at which projects move through the process and the level of resource that may be available.

Risk communication

Managing the risks from land contamination is not simply a matter for the land owner or occupier, the officials engaged in the regulatory process and technical and/or legal advisors and contractors who may also be involved in a professional capacity. The actual or potential presence of contamination may have direct or indirect consequences for a much broader constituency of people and organisations, including neighbouring property owners and the local community. These **stakeholders** may have legitimate concerns about the level of risk posed by a site, whether or not the risk is unacceptable and how best it should be reduced or controlled.

Communicating information about the risks associated with land contamination to parties not directly involved in a project is not necessarily straightforward. This is particularly the case when anxieties about the land may be at odds with technical or scientific assessments, or when there are major differences of opinion between the different groups about the best way of proceeding.

Therefore, a formal risk communication strategy will be an important element of many land contamination projects, especially for large, complex or otherwise high-profile sites or where the technical processes involved are likely to be particularly disruptive or time consuming. There are a number of ways of developing and delivering risk communication strategies at a site-specific level and *Communicating Understanding of Contaminated Land Risks* [6] contains further guidance on how best to approach this issue.

1.3 Risk management and the Model Procedures

Defining the context

The Model Procedures provides a technical framework for applying a risk management process to land affected by contamination. The framework focuses on individual sites, although it can also be used in the context of managing a portfolio of sites.

The overall structure of the Model Procedures reflects the approach described in the DETR, Environment Agency and Institute for Environment and Health publication, *Guidelines for Environmental Risk Assessment and Management* [4]. In line with this approach, at the outset of any land contamination project, it is critical to set out clearly the problem to be managed. As well as the practical dimensions of the problem, legal, commercial and financial factors also affect the decision-making process. These, and other boundaries within which any decisions will be made, should also be identified at the outset and updated throughout the process.

Engaging with stakeholders

An important part of defining the context is to identify the stakeholders who have an interest in the scope, conduct and outcome of a particular risk management project. Stakeholders can include a wide range of individuals and organisations, such as landowners, funders, purchasers, occupiers, regulators, advisors, neighbouring property owners and/or occupiers and the wider public.

Meaningful dialogue with all stakeholders is key to the successful outcome of risk management projects and is *essential* in relation to regulators who have specific statutory duties and powers for health and environmental protection in this area. It is important, therefore, that managers understand, and comply with, the specific legal requirements that may apply to a particular project and that they also observe good practice in terms of both formal and informal liaison and information sharing.

The process

The basic risk management process in the Model Procedures has three main components:

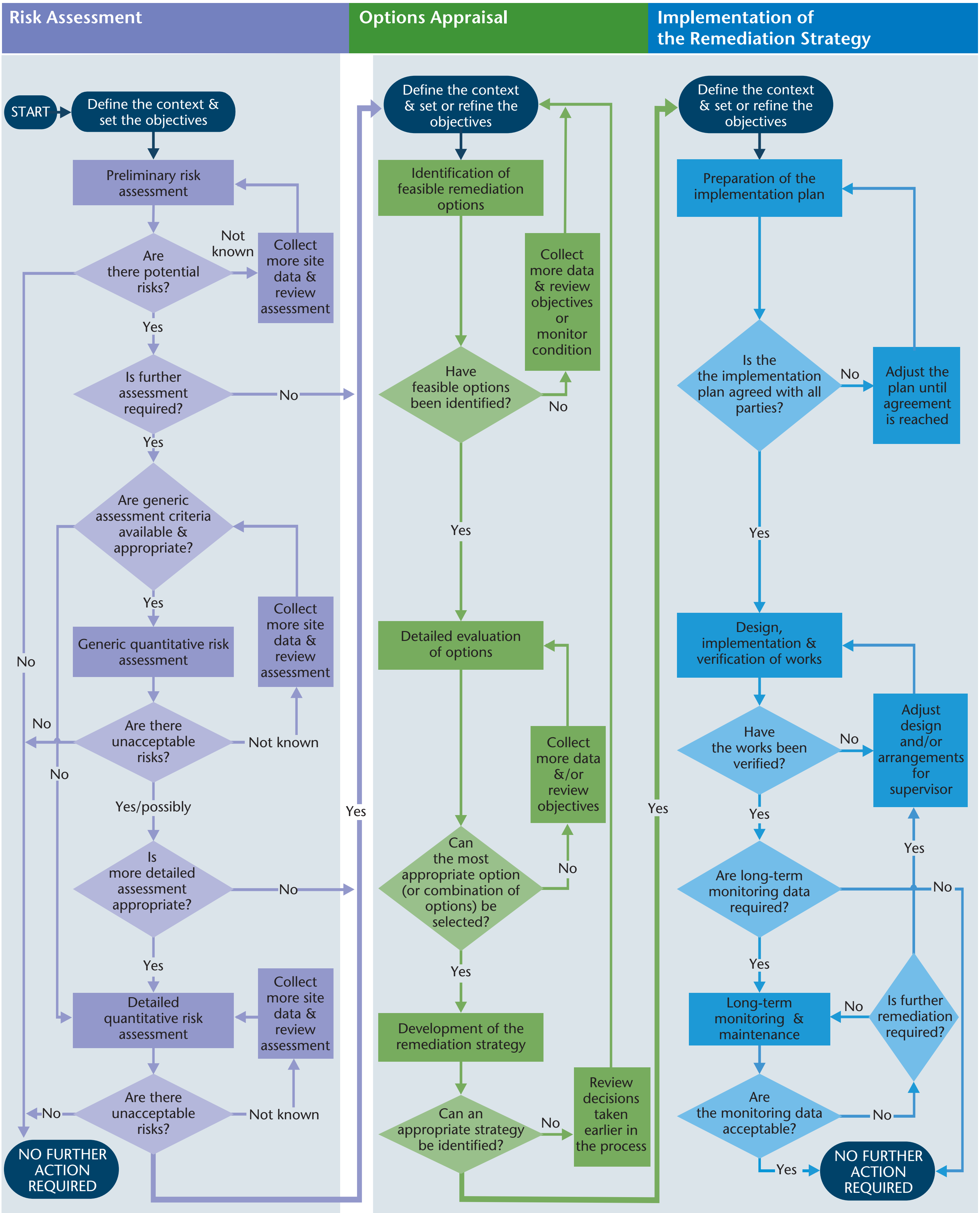
- Risk assessment – establishing whether unacceptable risks exist and, if so, what further action needs to be taken in relation to the site;
- Options appraisal – evaluating feasible remediation options and determining the most appropriate remediation strategy for the site;
- Implementation – carrying out the remediation strategy and demonstrating that it is, and will continue to be, effective.

Figure 1 sets out the process framework that has been adopted for the Model Procedures. The framework is intended to provide a structured and reasoned technical basis for making decisions about land contamination in an objective, consistent and transparent way, and to ensure that appropriate information is collected at relevant stages to underpin the process.

The process is phased, with scope for iteration within individual components. It also provides flexibility in terms of the possible response options for a particular set of conditions or findings, so that time and financial resources are used to best effect. For example, in some circumstances the process allows risk managers to move quickly to options appraisal and remediation, so an obvious problem can be resolved, rather than directing them to a more detailed risk assessment to demonstrate that the problem exists. In other cases, risk assessment will result in a judgement that no unacceptable risks arise from the contamination, and therefore there is no need to proceed with any consideration of remediation.

The procedures encourage the formalisation of outputs from the process. These include written records and reports that cover both what decisions were made (the Decision Record) and the way in which those decisions were reached. Further outputs may include specifications, design drawings and reports on the work actually carried out.

Note that throughout the process, it is essential to comply with all the requirements of health and safety legislation on the protection of any workforce engaged in land contamination projects, and of others who may be affected by such work.



Note: The process may apply to one or more pollutant linkages each of which may follow a different route. For some linkages, it may be possible to stop at an early stage – others will progress all the way through the process. The level of complexity of each stage may also vary and in some cases may be very simple.

Figure 1 | The Process of Managing Land Contamination

1.4 Using the Model Procedures

Application

The risk management framework set out in the Model Procedures is potentially applicable in a wide range of different contexts. Particular intended uses are:

- In relation to regulatory intervention under Part IIA of EPA 1990 or Part III of the Waste and Contaminated Land (Northern Ireland) Order 1997;
- During the "voluntary" investigation and remediation of land affected by contamination;
- As part of managing potential liabilities on an individual site or a portfolio of sites;
- During the redevelopment of sites that may be affected by contamination.

The Model Procedures provide a generic framework to show the key technical activities that may apply in each of these contexts, and identify the main decisions at each stage. They are not intended to present rigid technical requirements – the particular context in which the Procedures are applied, as well as the circumstances of an individual site, will determine both the specific technical detail of the process and the criteria for decisions.

It is important to note that the question of whether contamination originated in the past or is "new", as discussed above, has important implications for the applicability of the approach set out in the Model Procedures.

The overall approach is not, for example, directly applicable to site surrender reports prepared for sites permitted under IPPC (Integrated Pollution Prevention Control) or for decisions about the surrender of waste management licences, although some elements may be relevant in some cases. For instance, the technical principles that underlie the evaluation of remediation options can be used to decide the most appropriate way of remediating pollution caused by the ongoing activities of an installation permitted under the PPC Regulations. This is subject to the specific regulatory requirements of the PPC regime as discussed in section 1.1 above.

1.5 How the Model Procedures are presented

The Model Procedures consist of three parts – Procedures, Supporting Information and the Information Map. These provide a hierarchy of information, in which Part 1 sets out the framework of the process, Part 2 provides further technical detail to support the process and Part 3 contains sources of further information and guidance.

Part 1 – Procedures

Part 1 consists of five Chapters that cover (see *Figure 2*):

- An overview of the Model Procedures;
- The three key component of risk management – risk assessment, options appraisal and implementation of the remediation strategy;
- Key references and a glossary.

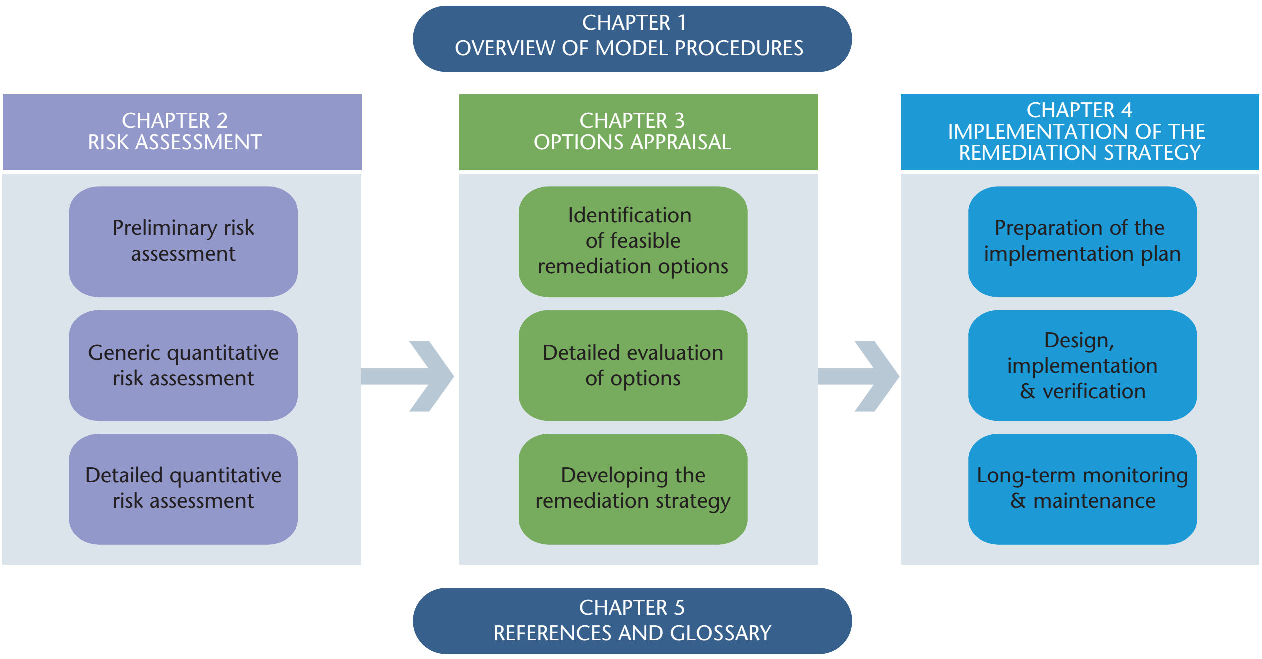


Figure 2 | Arrangement of Chapters in Part 1 of the Model Procedures

Each of Chapters 2, 3 and 4 contains an overview of the relevant part of the risk management process, including key features and a brief summary of the main technical aspects. The chapters then briefly describe the main stages involved in that part of the process and provide a flow chart that outlines the model procedure for carrying out each stage. Each flow chart includes key points relevant to following the process and links to supporting technical information located in Part 2 of the Model Procedures. This information is presented in the form of example "inputs", "tools", "criteria" and "outputs" for each part of the process.

Part 1 of the Model Procedures focuses on clearly defining the decision-making process, and the key principles that underpin it, rather than providing detailed information on particular technical activities or legal requirements. Readers should refer to Parts 2 and 3 of the Model Procedures for further technical detail, and to other sources of information and guidance, such as the websites of government departments and regulatory bodies, for information on legal requirements.

Part 2 – Supporting Information

Part 2 contains detailed supporting information to the procedures contained in Part 1, presented in the form of information boxes. These contain examples of the inputs, tools, criteria and outputs used or generated throughout the process of risk management. To facilitate the use of the information boxes, each is 'badged' using a coloured page banner, flow chart reference that links the information box to a particular process stage, and a symbol that indicates the type of information being presented.

Information boxes are current at the time of publication. They may not contain all the technical and other information needed to understand or complete a particular decision or activity. Readers should refer to other sources, as set out in the Information Map, for further information and guidance where necessary.

Part 3 – Information Map

The Information Map contains details of over 80 individual or sets of key publications that give more detailed technical guidance on particular aspects of the risk management process. All the documents have been issued by authoritative bodies, such as Defra and its predecessor departments, the Environment Agency and predecessors, the British Standards Institution and others.

Each entry in the Information Map sets out the title, date, report reference and publisher of the document or document set and its current status (published or in preparation). Contact details for copies of documents are also provided.

All the information sources listed are relevant to a good understanding of risk management in land contamination applications, but the Information Map is not exhaustive and other documents may be useful for certain users in particular circumstances. Readers should also be aware that information and guidance on land contamination are published and revised on a regular basis and they should ensure that the most up-to-date publications and/or information are used.

Who should use the Model Procedures?

The Model Procedures are expected to be of interest to all those involved in or responsible for managing land contamination, whether in the context of regeneration and redevelopment, voluntary assessment or remediation, or regulation.

Those responsible for the practical application of the risk management process are expected to find the overviews and procedures contained in Chapters 2, 3 and 4 of Part 1 of the Model Procedures (together with supporting and reference information in Parts 2 and 3) of value in providing a consistent framework for their activities. These may include project managers, individual experts and/or team leaders responsible for specific tasks. These individuals or teams will need to have appropriate experience and skills to apply the principles set out in the document in the relevant context. This might be demonstrated by qualifications and experience in a specific technical or scientific discipline or application, or by multidisciplinary qualifications, such as SiLC (Specialist in Land Condition).

Expected impact

Overall, the Model Procedures are intended to improve procedural understanding of a risk-based approach to land contamination and provide a consistent framework for decision making. This, in turn, should encourage the sharing of knowledge and good practice amongst professionals and others.

It is envisaged that the Model Procedures will provide an appropriate starting point for individual companies and organisations, such as landowners, developers, purchasers, funders and regulatory bodies, to review and develop their own procedures and supporting material to meet specific needs.

2

Risk Assessment

2.1 Overview

At the outset of the risk management process, the context of the problem and the objectives of the process must be identified (see Chapter 1, Section 1.3). This forms the starting point for risk assessment, which provides a structured mechanism for identifying risks and making judgements about the consequences. Risk assessment is an essential component in achieving effective management of the risks from land contamination and as such underpins both the Part IIA EPA 1990 regulatory regime and planning policy.

Risk assessment can be a highly detailed process, particularly where risks are complex and, in the case of land contamination, there are a range of specific technical approaches for different contaminants and circumstances. However, these approaches all broadly fit within a tiered assessment structure in line with the framework set out in the DETR, Environment Agency and Institute for Environment and Health Publication, *Guidelines for Environmental Risk Assessment and Management* [4]. The tiers are applied to the circumstances of the site under consideration with an increasing level of detail required by the assessor in progressing through the tiers.

The three tiers used in the Model Procedures for the specific context of land contamination are:

1 **Preliminary risk assessment;**

2 **Generic quantitative risk assessment;**

3 **Detailed quantitative risk assessment.**

Once the need for risk assessment has been identified, it will always be necessary to carry out a preliminary risk assessment. However, depending on the circumstances and the outcome, it may not be necessary to carry out further risk assessment, or it may be appropriate to use only one of the two approaches to quantitative risk assessment rather than both.

Once the risks are assessed, and if action to reduce or control the risks is considered necessary, the next part of the process is the appraisal of options to deal with the risks, followed by implementation of appropriate action. *Figure 2.1* illustrates the relationship between risk assessment and the later stages, and the key decisions in risk assessment that contribute to the overall risk management process.

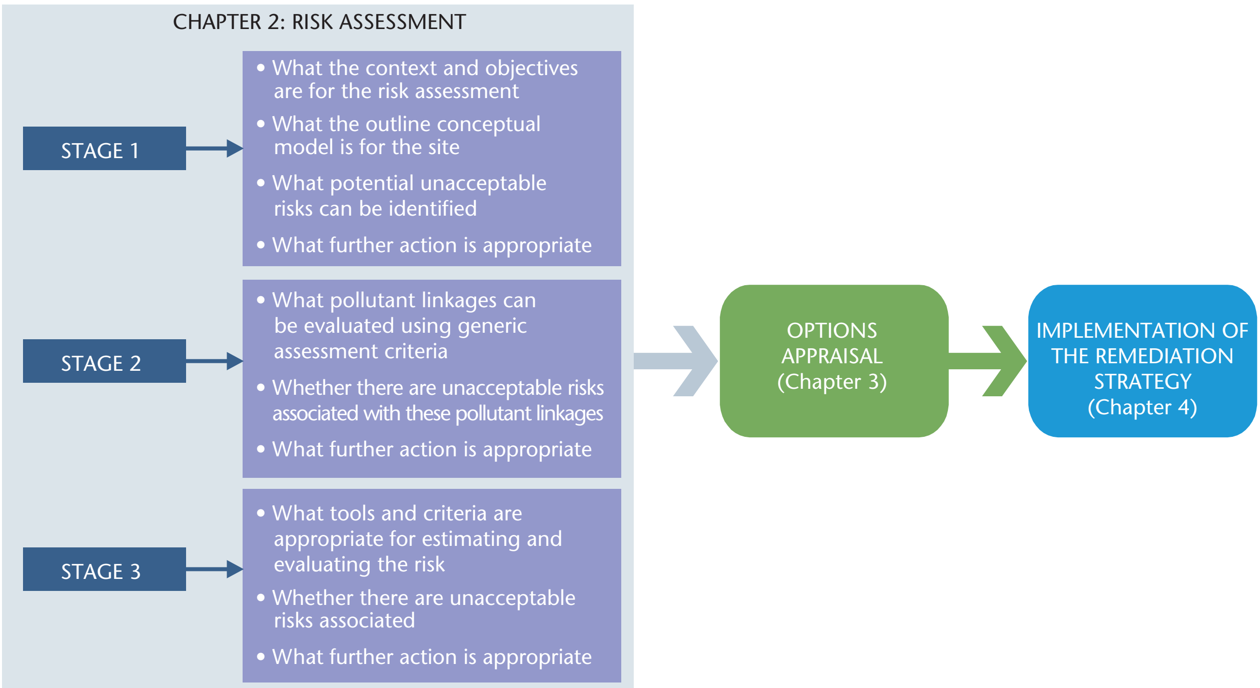


Figure 2.1 | Main Stages & Key Decisions

Particular features of risk assessment

The conceptual model
An important thread throughout the overall process of risk assessment is the need to formulate and develop a **conceptual model** for the site, which supports the identification and assessment of pollutant linkages. Development of the conceptual model forms the main part of preliminary risk assessment, and the model is subsequently refined or revised as more information and understanding is obtained through the risk assessment process.

> A **conceptual model** represents the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.
>
> The term **pollutant linkage** is used to describe a particular combination of contaminant–pathway–receptor.
>
> (See Chapter 1)

Different receptors may be relevant in different circumstances – it is important for those who carry out risk assessment to be very clear about the receptors, both on or off site, that are to be included in the assessment.

Moving through the process
It may be necessary to apply the process separately for some or all of the different pollutant linkages. The reasons for this could simply be the different technical approaches required, but it may also depend on the context or outcome of decisions about particular receptors, contaminants or pathways, or combinations of these.

The overall process of risk assessment is often iterative – more detailed assessment may raise issues that require the earlier tiers to be revisited. The process within each tier may also be iterative, especially when information is evaluated and gaps are identified in the knowledge needed to make a particular decision. In this case, approaches taken earlier within the tier may need to be reappraised.

In some circumstances it may be appropriate to exit the process part way through. This could arise when enough is known about the potential risk either to leave the process altogether, for example because no unacceptable risk has been identified, or to move straight to the next part of the process – options appraisal. This helps to ensure that the effort expended in risk assessment is proportionate to the circumstances of the activity – a key requirement for applying the process.

Information requirements
Each tier of risk assessment requires decisions to be made on the basis of information about the site – for example, the type, extent, location and behaviour of potential contaminants, physical conditions on or around the site and the characteristics of the people and the environment potentially affected by contaminants on the site. Information used in risk assessment may also be essential in informing decisions about possible solutions for managing the risk. A fundamental part of efficient decision making is therefore to ensure that the appropriate range and level of information is collected at each tier of risk assessment, and that this information meets appropriate **quality criteria**.

> **Quality criteria** for information:
>
> *Relevant* to the context of the risk assessment
>
> *Sufficient* for the required level of confidence
>
> *Reliable* in reflecting true or likely conditions
>
> *Transparent* in meaning and origin

Degree of confidence and uncertainties
The risk assessment process needs to take into account the degree of confidence required in decisions – this will be critical in circumstances where the answer is not immediately clear. This will depend on the circumstances – for example, a regulator responsible for the protection of people or the environment may want a high degree of certainty when carrying out a preliminary assessment to ensure the possibility of an unacceptable risk has not been missed, and is likely to take a precautionary view.

Identification of uncertainties is an essential step in risk assessment. Some uncertainties can then be reduced, for example by obtaining better data or refining models to improve their validity. All uncertainties need to be noted: some uncertainties can be quantified, for example by providing statistical confidence limits, whilst others may need more qualitative characterisation such as setting high, medium or low degrees of confidence on information or judgements. The overall aim is to ensure that the quality of information used and the overall degree of confidence associated with the analysis of that information provides a robust basis for decision making.

Criteria for judging whether or not there are unacceptable risks
The risk assessment process focuses on the question of whether there is an unacceptable risk, which will depend on the circumstances of the site and the

context of the decision. The selection of transparent and appropriate criteria is critical.

There can be different criteria for different receptors. For example, under the Part IIA regime, the criteria used to establish whether a site is **contaminated land** (and hence could require remediation) vary according to whether human health, ecosystems or other receptors are at risk (see Table B, Chapter A, Annex 3 of DETR Circular 02/2000 [1]).

These **evaluation criteria**, and similar ones in other regimes, are set in relation to a level of harm or pollution to the specific receptor. They may be translated into absolute standards or recommended limit values (e.g., a **health criteria value** for the intake of a substance), again measured in relation to the receptor. They may also have been translated into guideline values or, in some cases, mandatory values for the concentrations of the contaminant in the soil or at some point on a particular pathway.

Technical aspects

The basic approach

In general terms, each tier of risk assessment follows the same basic steps – broadly equivalent to those set out in *Guidelines for Environmental Risk Assessment and Management* [4] (see Box).

> **Hazard identification** – establishing contaminant sources
>
> **Hazard assessment** – analysing the potential for unacceptable risks (what pathways and receptors could be present, what pollutant linkages could result and what could the effects be)
>
> **Risk estimation** – predicting the magnitude and probability of the possible consequences (what degree of harm or pollution might result and to what receptors, and how likely is it) that may arise as a result of a hazard
>
> **Risk evaluation** – deciding whether a risk is unacceptable

Choosing the right technical approach

Although the overall process stages are similar, different contaminants or receptors may require very different specific approaches and emphasis. For example, the process of assessing explosion risks from landfill gas relies primarily on detailed knowledge of gas production rates in the ground and potential for accumulation in explosive concentrations, whereas the assessment of risks to human health from mercury contamination in soil requires detailed knowledge of the vulnerability of humans and the mechanism of their exposure to the mercury. As a result, at each stage of the process the assessor must choose the most appropriate technical tool – for example, a model designed for the linkage under consideration – to support the risk assessment.

Information collection and site investigation

Information collection also requires the selection and implementation of an appropriate approach to investigation. Techniques include the collection of historical information, simple visual inspection of the site, taking samples from trial pits or auger holes and the installation of semi-permanent monitoring equipment. In many cases the investigation will be phased, not only to match the level of detail required for the tier of risk assessment, but also to allow for further refinement depending on the information obtained.

The variability of contaminated sites, and consequent potential for variability in results, is high. Site investigation needs to be designed to capture representative information about all relevant aspects of the site. A wide range of statistical techniques and other approaches to obtaining corroborative evidence may be needed to ensure that the site characterisation data are fit for the purpose of risk assessment.

The process of site inspection, especially where it involves sampling and analysis of different substances in different media, therefore requires careful design. This is to ensure that sufficient, relevant data are collected from the right locations, at the right time or over appropriate time periods, using equipment, techniques and methods that will not compromise the technical validity of the data obtained. Note that certain specific requirements, such as compliance with the Environment Agency's policy on the analysis of soil and water samples according to the **Monitoring Certification Scheme (MCERTS)**, may apply. All such data collection activities should be subject to documented **quality management** procedures and data presentation should be transparent in origin and meaning.

Sources of technical guidance

Parts 2 and 3 of the Model Procedures provide details of a range of technical guidance and tools to assist in applying the risk assessment process in particular circumstances.

2.2 Preliminary risk assessment

Outline of this stage of Model Procedures

The *purpose* of preliminary risk assessment is to develop an initial conceptual model of the site and establish whether or not there are potentially unacceptable risks.

At the *beginning* of this stage the person who carries out the risk assessment – the **assessor** – has identified the site to be considered and the context for the risk assessment.

During this stage the assessor collects and reviews largely desk-based information to prepare an initial conceptual model to identify possible pollutant linkages. The assessor then evaluates the possible linkages, using criteria appropriate to the risk assessment context.

Information collection may include:

- **Desk study**
- **Site reconnaissance**
- Additional desk study and exploratory site investigation

The next steps are to decide whether or not further action is needed. This may be more detailed risk assessment, or it may be appropriate to move straight to options appraisal, for example when a clear risk has been identified and the need for remediation can be established. The preliminary assessment may also indicate that there is not a potential risk, that further information is needed to complete this stage or that the site needs to be kept under review.

Decisions

At the *end* of this stage, the assessor should have established:

- What the context and objectives are for the risk assessment;
- What the outline conceptual model is for the site;
- What potential unacceptable risks can be identified;
- What further action is appropriate.

Outputs

Key outputs from this stage are:

- **Decision Record** – a summary of context and objectives, the outline conceptual model, the potentially unacceptable risks and the proposed next steps in relation to the site.
- An *explanation* of the background to the risk assessment, the basis for the development of the conceptual model, the evaluation of the potential risks and the basis for the decision on what happens next.

Technical activities

The steps shown in *Figure 2A* set out the model procedure for carrying out a preliminary risk assessment. The banners to the right show the location of key supporting information in Part 2 of the Model Procedures.

KEY PROCEDURAL POINTS

KP1
This will be determined by the overall context for risk management

KP2
This will be largely desk-based research & site reconnaissance

KP3
A typical response would be to return to Step 3

KP4
This decision will depend on the objectives of the risk assessment & priorities for this site in the light of wider priorities

KP5
This will depend both on the overall context & on the types of risk identified

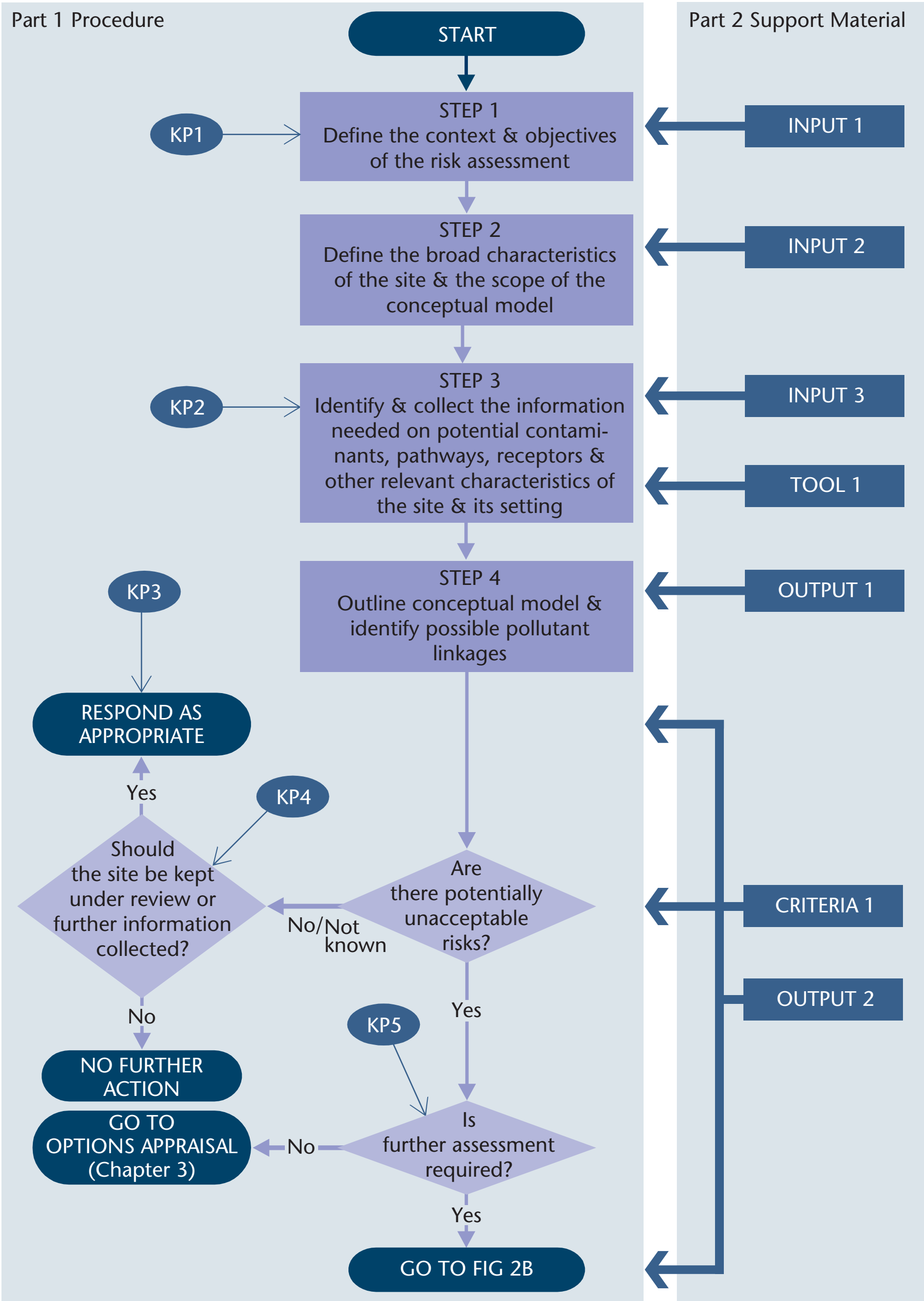


Figure 2A | Preliminary Risk Assessment

2.3 Generic quantitative risk assessment

Outline of this Stage of Model Procedures

The *purpose* of generic quantitative risk assessment is to establish whether **generic assessment criteria** and assumptions are appropriate for assessing the risks and, if so, to apply them to establish whether there are actual or potential unacceptable risks. It also determines whether further detailed assessment is required.

> **Generic assessment criteria** are criteria derived using largely generic assumptions about the characteristics and behaviour of sources, pathways and receptors. These assumptions will be conservative in a defined range of conditions

At the *beginning* of this stage the assessor has an outline conceptual model for the site and the context of the risk assessment, and has identified some potential pollutant linkages of concern that justify further assessment.

During this stage the assessor considers the availability and appropriateness of generic assessment criteria to simplify the assessment of the site. If generic assessment criteria can be used or developed for some or all of the pollutant linkages, the assessor determines what information (e.g., about contaminants, pathways and receptors and other properties of the site and its setting) is needed to apply the criteria in an appropriate way.

Further information is then collected about the site and its surroundings through intrusive site investigation. This includes information on the actual presence and extent of contaminants, pathways and receptors that may form pollutant linkages and give rise to unacceptable risks, and information on other characteristics of the site that are relevant to the risk assessment and decision making process.

> Information collection may include:
>
> - Staged intrusive site investigation
> - Supplementary site investigation, data review and analysis

The assessor refines the conceptual model as a result of the investigations, and pollutant linkages are confirmed for evaluation. If appropriate, the assessor uses generic assessment criteria to assess one or more pollutant linkages.

The final part of this stage is consideration of the next steps: this can include further work to complete the generic quantitative risk assessment or detailed quantitative risk assessment, for example when generic assessment criteria are not appropriate or sufficient to assess the risk. Assessment using generic assessment criteria may also lead straight to the stage of options appraisal or, where no potential health and environmental risks have been identified, to an exit from the process.

Decisions

At the *end* of this stage, the assessor should have established:

- What pollutant linkages can be evaluated using generic assessment criteria and assumptions;
- Whether unacceptable risks associated with these linkages can be identified;
- What further action is appropriate.

Outputs

Key outputs from this stage are:

Decision Record – the pollutant linkages identified based on the development of the conceptual model; the generic assessment criteria used to assess risks; the unacceptable risks identified; and the proposed next steps in relation to the site.

An *explanation* of the development of the conceptual model (in particular the results of site investigation); the selection of criteria and assumptions; the evaluation of the potential risks; and the basis for the decision on what happens next.

Technical activities

The steps shown in *Figure 2B* set out the model procedure for carrying out generic quantitative risk assessment. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1

This may require updating the output from the preliminary risk assessment stage

KP2

These will depend on the management context of the site

KP3

This requires separate consideration of each potential pollutant linkage

KP4

In some cases it may be more cost effective to move straight to options appraisal, but this will mean that risk assessment objectives will need to be amended

KP5

This applies for each pollutant linkage

KP6

Depending on the risk assessment context, options might include:

- *Keep the assessment under review*
- *Collect further information*
- *Carry out detailed quantitative risk assessment*
- *Move to the risk management stage*

KP7

This will depend on the context of the risk assessment & site circumstances. For example, it may be necessary to collect more information to refine this stage of assessment or to carry out detailed quantitative risk assessment on the site as a whole or on particular linkages

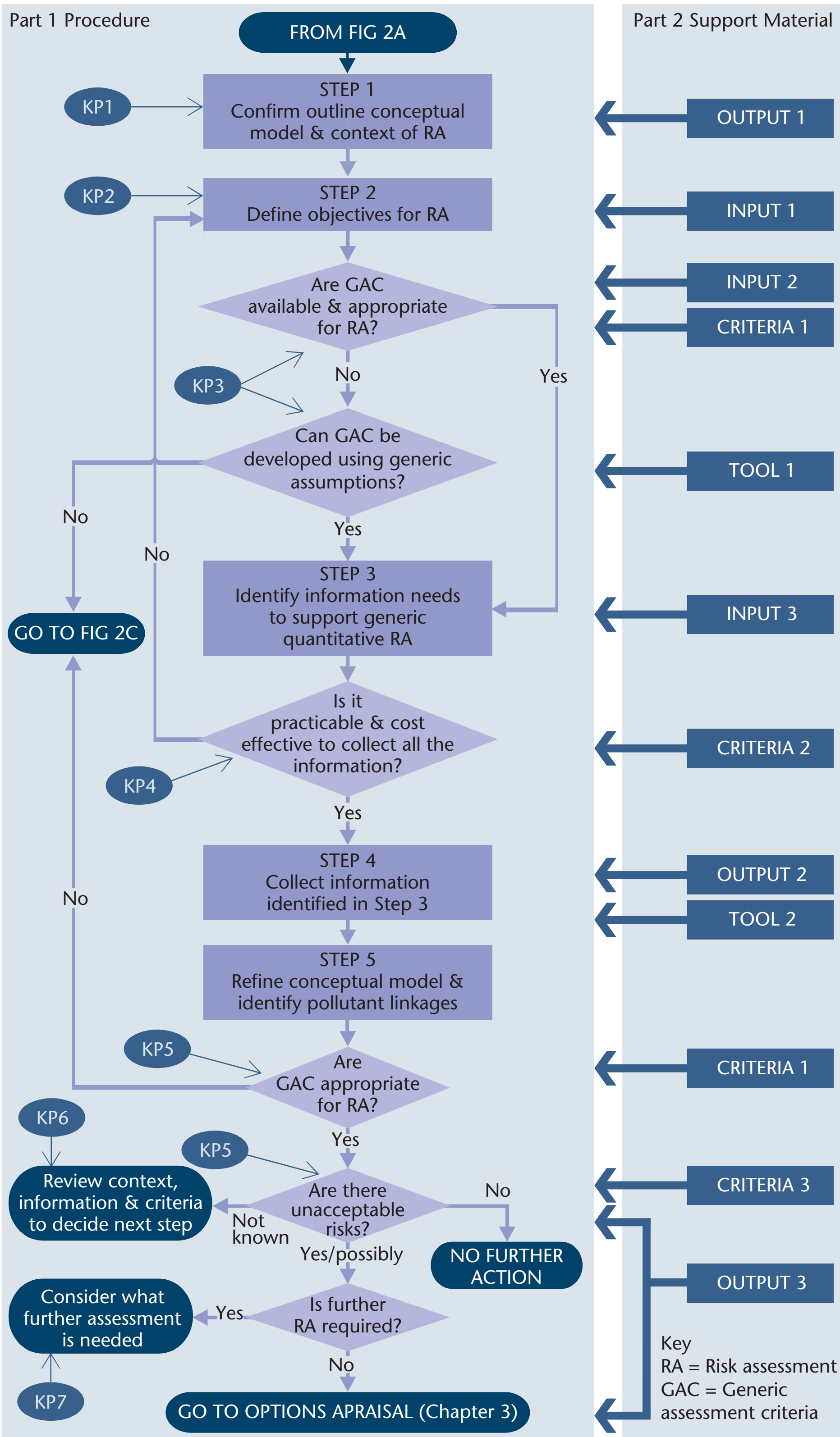


Figure 2B | Generic Quantitative Risk Assessment

2.4 Detailed quantitative risk assessment

Outline of this stage of Model Procedures

The *purpose* of detailed quantitative risk assessment is to establish and use more detailed site-specific information and criteria to decide whether there are unacceptable risks. It may be used as the sole method for quantitative assessment of risks, or it may be used to refine earlier assessments using generic assessment criteria.

At the *beginning* of this stage, the assessor has an outline conceptual model for the site and knows the context of the risk assessment. The assessor has also identified pollutant linkages that require further detailed assessment. Some may have already been assessed using generic assessment criteria, but there could be pollutant linkages for which generic assessment criteria:

- Are not available or appropriate given the actual circumstances of the site;
- Are more conservative than is appropriate given the actual circumstances of the site.

It may be the case that the site as a whole may be sufficiently complex that interactions between pollutant linkages require more detailed assessment.

During this stage the assessor identifies or develops tools and criteria to estimate and evaluate the risk. This may include the development of detailed **site-specific assessment criteria**.

> **Site-specific assessment criteria** are values for concentrations of contaminants that have been derived using detailed site-specific information on the characteristics and behaviour of contaminants, pathways and receptors, and that correspond to relevant criteria in relation to harm or pollution for deciding whether there is an unacceptable risk.

Depending on what is already known about the site and the tools to be used, the assessor may need further information, not only on the pollutant linkages and other characteristics of the site and its surroundings, but also on other parameters to develop risk estimation models and site-specific assessment criteria. The assessor will also need to establish appropriate evaluation criteria for the risks to decide which are unacceptable.

The assessor refines the conceptual model as a result of the investigations, and confirms what pollutant linkages need to be evaluated. The assessor then carries out risk estimation and evaluation.

The final part of this stage is to consider the next steps: this can include further information collection to complete the assessment, a review of the assessment or a decision to move to options appraisal or, where no unacceptable risks have been identified, to an exit from the process.

Decisions

At the *end* of this stage the assessor should have established the following:

- What tools and criteria are appropriate for estimating and evaluating the risks from particular pollutant linkages;
- Whether unacceptable risks associated with these linkages can be identified;
- What further action is needed.

Outputs

Key outputs from this stage are:

- *Decision Record* – the pollutant linkages identified based on the development of the conceptual model; the tools and criteria used to estimate and evaluate risks; the unacceptable risks identified; and the proposed next steps in relation to the site.
- An *explanation* of the development of the conceptual model (in particular the results of site investigation); the development and choice of criteria, tools and assumptions for risk estimation; the evaluation of the potential risks; and the basis for the decision on what happens next.

Technical activities

The steps shown in *Figure 2C* set out the model procedure for carrying out detailed quantitative risk assessment. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1

The decision to carry out a detailed quantitative risk assessment may be made at a number of earlier points in the overall process

KP2

This may require updating the output from the preliminary risk assessment stage

KP3

This applies for each pollutant linkage

KP4

Depending on the risk assessment context, options might include:

- *Keep the assessment under review*
- *Collecting further information*
- *Moving to the risk management stage*

KP5

This depends on the context of the risk assessment & site circumstances. For example, it may be necessary to obtain more information to quantify risks in more detail or establish the mechanisms by which risks are created

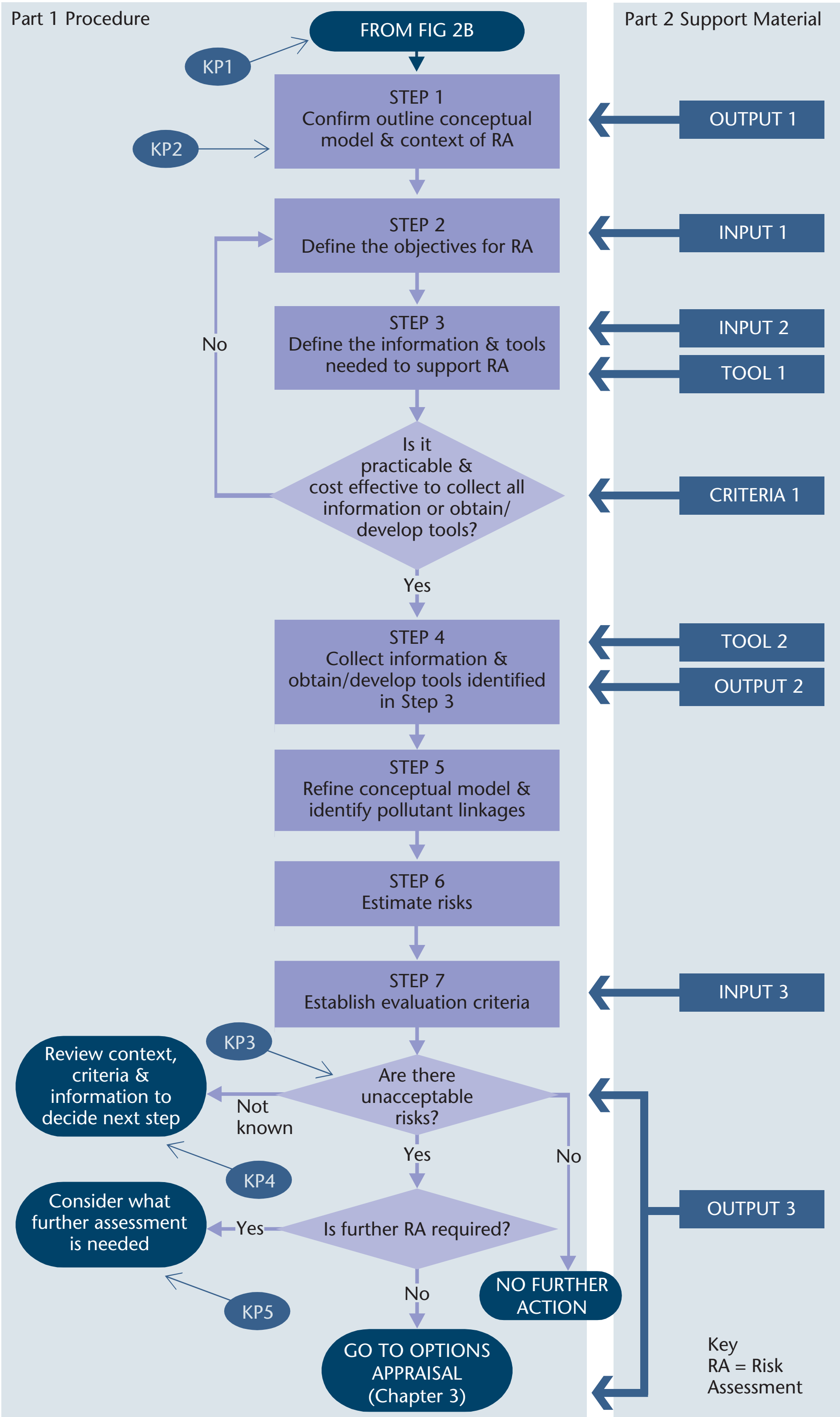


Figure 2C | Detailed Quantitative Risk Assessment

3

Options Appraisal

3.1 Overview

Options appraisal is the second stage of the overall process of risk management in the Model Procedures. It comes into play only if risk assessment demonstrates unacceptable risks are associated with a site and these need to be managed. As options appraisal proceeds, therefore, it focuses primarily on those pollutant linkages (relevant pollutant linkages, RPLs) that have been shown through risk assessment to represent unacceptable risks (given the legal and commercial context) and where a decision has been made to undertake remediation.

In practice, there may be a number of a ways to reduce or control unacceptable risks, all of which have advantages and limitations in any particular case. The role of options appraisal is to establish, taking all the circumstances of the site into account, which options (either singly or in combination) offer the best overall approach to remediation for the site as a whole.

There are three main stages of options appraisal:

1 Identifying feasible **remediation options** for each relevant pollutant linkage;

2 Carrying out a detailed evaluation of feasible remediation options to identify the most appropriate option for any particular linkage;

3 Producing a **remediation strategy** that addresses all relevant pollutant linkages, where appropriate by combining remediation options.

Once a remediation strategy has been identified and agreed, the process of risk management continues with the detailed planning and design work needed to implement the strategy in practical terms and show that it has been effective. *Figure 3.1* sets out the key decisions at each stage of options appraisal, and the relationship between options appraisal and the processes of risk assessment and implementation of the remediation strategy.

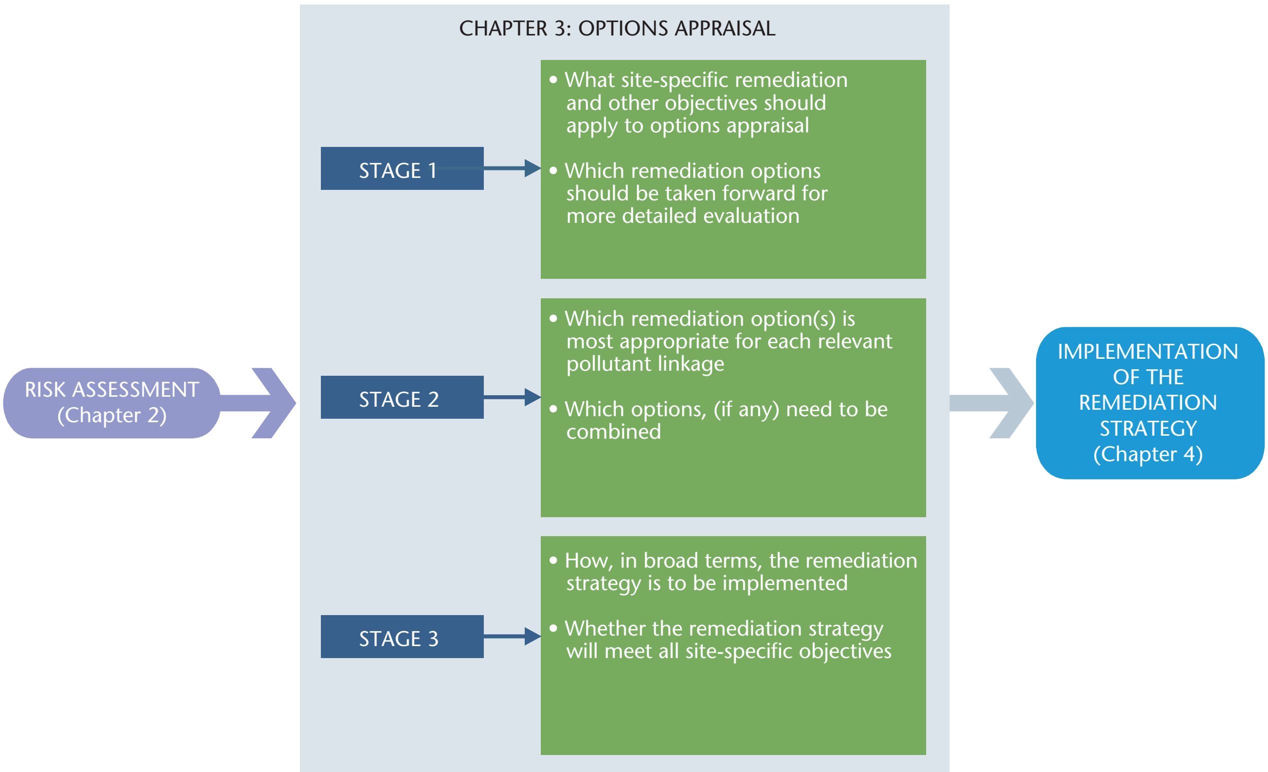


Figure 3.1 | Main Stages & Key Decisions

Particular features of options appraisal

Choosing the right technical approach

The process of options appraisal is similar to other well-established environmental procedures, such as Best Available Technique (BAT) assessments, in which the best overall solution to an environmental problem is identified through the evaluation of a range of management and technical factors and cost. The identification of the Best Practicable Technique (BPT) in accordance with statutory guidance represents an equivalent process under Part IIA [1].

For the purpose of these Model Procedures, a **relevant pollutant linkage** is one that has been identified through risk assessment as representing unacceptable risks to human health or the environment.

A **remediation option** is a means of reducing or controlling the health or environmental risks associated with a particular pollutant linkage.

A **remediation strategy** is a plan that involves one or more remediation options to reduce or control the risks from all the relevant pollutant linkages associated with the site.

During options appraisal, each relevant pollutant linkage is considered on an individual basis in the first instance, and the most appropriate remediation option is identified using a set of formal evaluation criteria. If only one pollutant linkage has to be considered, or if a single remediation option will deal satisfactorily with all the relevant pollutant linkages, that remediation option forms the basis of the remediation strategy for the site as a whole. Where more than one relevant pollutant linkage exists, it may be possible to combine remediation options to produce the remediation strategy or to identify a different option.

Note that the presence of unacceptable risks may not always result in a technical or engineering response. For example, it may be decided that the best approach is to change the use of the site to one that is less sensitive to the presence of the pollutants. In these cases, the conceptual model upon which the risk assessment was based needs to be revised to demonstrate that remediation is no longer required.

Site-specific factors

All remediation options have advantages and limitations that make them more or less applicable in any particular case and a wide range of site-specific technical factors determine which remediation options are most appropriate. Some of these factors relate to the nature of the relevant pollutant linkages, such as the type, amount, lateral and vertical distribution of pollutants and affected media, and the properties of pathways. Others relate to the general characteristics of the site, such as its size, location, accessibility, topography and wider environmental setting, and the existence (or proposed construction) of buildings and other structures. The current or intended use of the site also needs to be taken into account to ensure that remediation does not compromise soil functions, including geotechnical properties.

Other factors also affect the choice of the most appropriate option. These include the legal and commercial context within which the site is being handled; the views of key stakeholders (such as site owners, purchasers, funders, regulators and the local community), and the costs and benefits of using any particular option.

Setting objectives at the outset

Once relevant pollutant linkages have been identified by reference to the conceptual model produced as a result of risk assessment, an important task is to define the boundary within which remediation options are considered so that potential conflicts between different objectives can be addressed and the most appropriate overall decision can be made. One way to define this boundary is to specify at the outset of options appraisal a series of objectives that the remediation strategy has to achieve to be considered acceptable to all those involved.

Objectives will be linked to the:

- Degree to which risks need to be reduced or controlled;
- Time within which the remediation strategy is required to take effect;
- **Practicability** of implementing and, where appropriate, maintaining the strategy;
- Technical **effectiveness** of the strategy in reducing or controlling risks;
- **Durability** of the strategy (i.e., will it provide a robust solution over the design life?);
- Sustainability of the strategy (i.e., how well it meets other environmental objectives, for example on the use of energy and other material resources, and avoids or minimises adverse **environmental impacts** in off-site locations, such as a landfill, or on other environmental compartments, such as air and water);
- Cost of the strategy (bearing in mind that the person who makes the decision about remediation may not be the person who has to pay);

- Benefits of the strategy – all remediation strategies should deliver direct benefits (the reduction or control of unacceptable risks) – but many have merits that extend well beyond the boundaries of the site; for example, remediation may enhance the amenity or ecological value of an area or contribute towards improved economic activity by removing blight or encouraging regeneration;
- Legal, financial and commercial context within which the site is being handled including the specific legal requirements that remediation has to comply with, and the views of stakeholders on how unacceptable risks should be managed.

Remediation objectives relate directly to the need to address pollutant linkages by one or more means. This may be achieved by decreasing contaminant mass, concentration, mobility or toxicity; by effective containment of the contaminant; or through the management of the receptor or pathway.

Once remediation objectives have been determined, site-specific **remediation criteria** need to be developed. Remediation criteria provide a measure (usually, but not necessarily, expressed in quantitative terms) against which compliance with remediation objectives can be measured. Examples of quantitative measures include:

- Guideline values (e.g., soil guideline values, drinking water standards);
- Site-specific assessment criteria developed from detailed quantitative risk assessment;
- Engineering-based criteria (e.g., the thickness and permeability of a cover system).

A **remediation objective** is a site-specific objective that relates solely to the reduction or control of the risks associated with one or more pollutant linkages.

Remediation criteria provide measures (usually, but not necessarily, expressed in quantitative terms) against which compliance with remediation objectives will be assessed.

Remediation criteria may consider the pollutant mass or concentration (e.g., no treated material shall contain more than 450 mg/kg of lead) or relate to a component of the remediation option (e.g., the hydraulic conductivity of an in-ground barrier shall not exceed a defined value).

Need to balance different factors

In some cases, it may prove difficult to identify remediation options and strategies that will meet some or all of the specified objectives completely. For example:

- There may be uncertainty about whether, in practice, a particular option will reduce or control risks to the required level;
- A technically effective way of dealing with a pollutant (e.g., biological treatment over a long period of time) may conflict with the time available for remediation (short 'window' within which funding and other resources are available) or be precluded for reasons such as the size, location or topography of the site;
- The most effective, practicable and durable solution may simply be too expensive given the nature of the risks and the benefits to be gained.

There may be differing views amongst stakeholders about what constitutes appropriate remediation: for example, the site owner's view about what is sufficient to redevelop a site, the regulator's view as to what is required on legal grounds or to comply with best practice, and the views of neighbouring property owners about what needs to be done to protect their land. The selection and evaluation process has to be able to balance all these factors so the necessary decisions can be made, bearing in mind that regulatory approval will often be the key driver.

Where there appear to be no options that will meet remediation and other objectives, it may be necessary to review the initial basis upon which options appraisal has been carried out. Sometimes other technical solutions may come forward or it may be possible to accept a lesser standard of remediation (e.g., by changing the layout or use of the site) or to make adjustments in other areas, such as providing additional health and safety protection or carrying out long-term monitoring.

In some cases (e.g., where the location of pollutants makes it impossible to carry out remediation effectively) it may be necessary to implement a long-term monitoring programme to track changes in the behaviour and movement of pollutants. Such a decision and all the associated monitoring work should be fully documented and a monitoring plan, which incorporates objectives, methods and criteria, needs to be produced (see Chapter 4.4).

Need for flexibility

Defining appropriate remediation is not always straightforward, since all decisions may be subject to close scrutiny by a range of different parties and there may be conflicting objectives. Individual site circumstances can also vary widely, with some sites having severe and complex contamination problems whilst others may be relatively simple to deal with.

Options appraisal has to be able to accommodate all sites within this range and an important consideration, therefore, is how wide-ranging the review of remediation options should be in any particular case. This will be determined by the nature and complexity of the problem, how many options (in practice) might be available for use at a reasonable cost and the time available to make the necessary decisions. In some cases, therefore, it will be appropriate to examine (especially in the early stages of options appraisal) as wide a choice of remediation options as possible commensurate with the time and financial resources available for the task. In other cases, it may be evident at a relatively early stage that only one feasible remediation option is likely to be available and so a detailed evaluation of a range of alternative options is not appropriate.

Technical aspects

The basic approach

There are three main ways to reduce or control unacceptable risks in land contamination applications:

1 Remove or treat the (source) of pollutant(s);

2 Remove or modify the pathway(s);

3 Remove or modify the behaviour of receptor(s).

Within each of these categories, there may be different technical options. For example, it is possible to remove or treat pollutants using a variety of physical, chemical or biological means.

Remediation techniques may also be applied on an **ex-situ** or **in-situ** basis (see Box).

Ex-situ – where contaminated material is removed from the ground prior to above-ground treatment or encapsulation and/or disposal on or off-site.

In-situ – where contaminated material is treated without prior excavation (of solids) or abstraction (of liquids) from the ground.

Possible limitations

Some approaches to remediation are not applicable in certain contexts. For example, in situations that involve controlled waters it is usually not possible to remove the receptor, although it may be possible to modify its behaviour (e.g., control the sub-surface flow of groundwater using hydraulic means) or limit the uses to which abstracted water is put. In human health applications in residential settings, it may be possible to remove the receptor (e.g., to re-house affected residents), and/or control an individual's exposure to pollutants by administrative means (e.g., imposing legal or contractual restrictions on their access to, or use of, a garden or play area).

Most of the techniques described above involve taking measures that actively deal with one or more component of the pollutant linkage. For certain readily degradable pollutants, natural processes of degradation and attenuation may be suitable for managing the RPL within an acceptable time period. In such circumstances, comprehensive long-term field monitoring and modelling are likely to be required to support such a decision.

Information requirements

Very specific information (about the pollutant, the nature, location and amount of source material, etc.) may be required to evaluate different options reliably. Some of this information may already be available as a result of intrusive site investigations carried out to support the risk assessment. However, during options appraisal, it may be necessary to collect supplementary site investigation data to further refine the technical understanding of the nature and scale of the pollutant linkage, the characteristics of the site and the risks associated with implementation of a remediation option.

In certain circumstances it may be necessary to establish, using laboratory or field-scale trials, how particular options are likely to perform in practice. For example, field-scale studies will be required to provide the data needed to support the design of a full-scale in-situ remediation strategy. However, laboratory and field-scale **treatability studies** can be expensive and time consuming to carry out and are usually only considered for remediation options that, on the basis of existing information, stand a good chance of being selected for use.

Components of remediation options and combining options

An individual remediation option may consist of a number of activities or operations that have to be carried out to deal fully with a particular pollutant linkage. The full sequence of treatment activities or options maybe referred to as a **treatment train** or an integrated solution. For example, excavated contaminated soils may go through a sequential process of screening (to remove non-soil debris) and sorting with subsequent treatments of the separated fractions. This could include, for example, further chemical, physical or biological treatment of contaminated fractions and effluent waters. Careful planning and design is required to ensure that each component activity is carried out smoothly and efficiently on site (see Chapter 4).

In some cases, using only one remediation option may not be sufficient to deal with all the problems of the site; more than one pollutant linkage may need to be addressed, or the most appropriate remediation option for one linkage may not be the most appropriate for another. In these cases, the remediation strategy may consist of one or more appropriate remediation options. For example, in a redevelopment scheme, biological treatment may be selected to deal with contamination in the soils that pose unacceptable risks to human health and a second option (e.g., air sparging) may be used to deal with dissolved phase liquids in the groundwater. Such a combined approach may be considered a treatment train.

To ensure that a remediation strategy consisting of more than one remediation option works effectively in practice requires even more care during planning and detailed design (see Chapter 4). For example, it may be necessary to zone the site and phase remediation work in such a way that different remediation options can be implemented without interruption, delay or error. It may be both practicable and cost-effective to combine certain components of different options leaving others to proceed independently. For example, the excavation of contaminated soils or primary treatment of abstracted contaminated liquids in an on-site treatment plant may be common elements of more than one remediation option.

Ensuring fitness for purpose

Developing a remediation strategy around a series of defined objectives using a structured process of options appraisal is an essential part of the risk management process. It should ensure that:

- Stakeholder views are identified and considered in a balanced and transparent way;
- The full range of legal, commercial and technical issues that will have a bearing on remediation are well known in advance of implementation;
- An objective assessment is carried out of the advantages, limitations and costs of different remediation options.

Options appraisal also provides the opportunity to ensure that the likely performance of remediation is considered *before* significant resources are devoted to detailed design and implementation. This should include the key question of how the attainment of remediation objectives is to be demonstrated, both at the time the remediation strategy is put into practice and, if appropriate, over its design life. The overall effect should be to minimise the chance of costly mistakes and increase confidence that the remediation strategy adopted for use is fit for its intended purpose.

Sources of technical information

Parts 2 and 3 of Model Procedures provide details on a range of technical guidance and tools to assist in the process of options appraisal.

3.2 Identification of feasible remediation options

Outline of this stage of Model Procedures

The *purpose* of this stage of options appraisal is to identify a shortlist of feasible remediation options for each relevant pollutant linkage, taking all the circumstances of the site into account.

An important first task is to review and refine the conceptual model produced at the end of the risk assessment so that it correctly identifies the pollutant linkages that require remediation.

At the *beginning* of this stage, therefore, the person who carries out the options appraisal – the **appraiser** – knows which pollutant linkages are to be subject to remediation.

A *feasible* remediation option is one that is likely to meet defined, site-specific objectives relating to both the pollutant linkage and the wider management context for the site as a whole.

A *manageable short list* means a list of feasible remediation options (preferably more than one option) that can be sensibly examined in more detail in the next stage of options appraisal.

During this stage the appraiser identifies site-specific remediation objectives for each relevant pollutant linkage. These will depend on the context within which unacceptable risks are to be managed (e.g., ongoing use of the land for an existing purpose; the redevelopment of the land for another purpose). The appraiser also identifies **management objectives** and other technical objectives (i.e., objectives in addition to those relating solely to pollutants) that need to be considered during the selection of remediation options. A range of site-specific constraints that affect the feasibility of applying different remediation options are also identified at this stage.

The appraiser also collects information on the broad characteristics of different remediation options to decide which are most likely to satisfy site-specific objectives. It may be necessary to collect additional site information to complete this stage of options appraisal and to review and, if necessary, amend site-specific objectives to ensure that feasible options can be identified.

In some cases it may be evident that only one feasible option is available for the remediation of the site. In these cases, further detailed evaluation of options is unnecessary and the appraiser may move quickly through the remaining steps of options appraisal and hence to the implementation stage of risk management. In other cases, however, appraisers will have a choice of feasible options and selection of the most appropriate one can only be determined by more detailed analysis.

Decisions

At the *end* of this stage the appraiser should have decided:

- What site-specific objectives relating to pollutants and to other technical and management issues are relevant to the selection of remediation options.
- Which remediation options should be taken forward for more detailed evaluation.

Outputs

Key outputs from this stage are:

- *Decision record* – the site-specific objectives and the shortlist of remediation options.
- An *explanation* of the basis on which the selection of objectives and feasible remediation options was made.

Technical activities

The steps shown in *Figure 3A* set out the model procedure for carrying out this stage of options appraisal. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1

Key output from risk assessment (see Chapter 2)

KP2

These should be based on the nature of the RPL and the wider technical & management context within which the site is being handled

KP3

For example, this may involve supplementary intrusive investigation of the site to determine the full lateral and vertical extent of the pollutant & other relevant ground properties

KP4

In some cases, the only feasible response to the condition of the site may be to implement a long-term monitoring programme to track changes in the behaviour or movement of pollutants. This decision, and all associated monitoring work, should be fully documented.

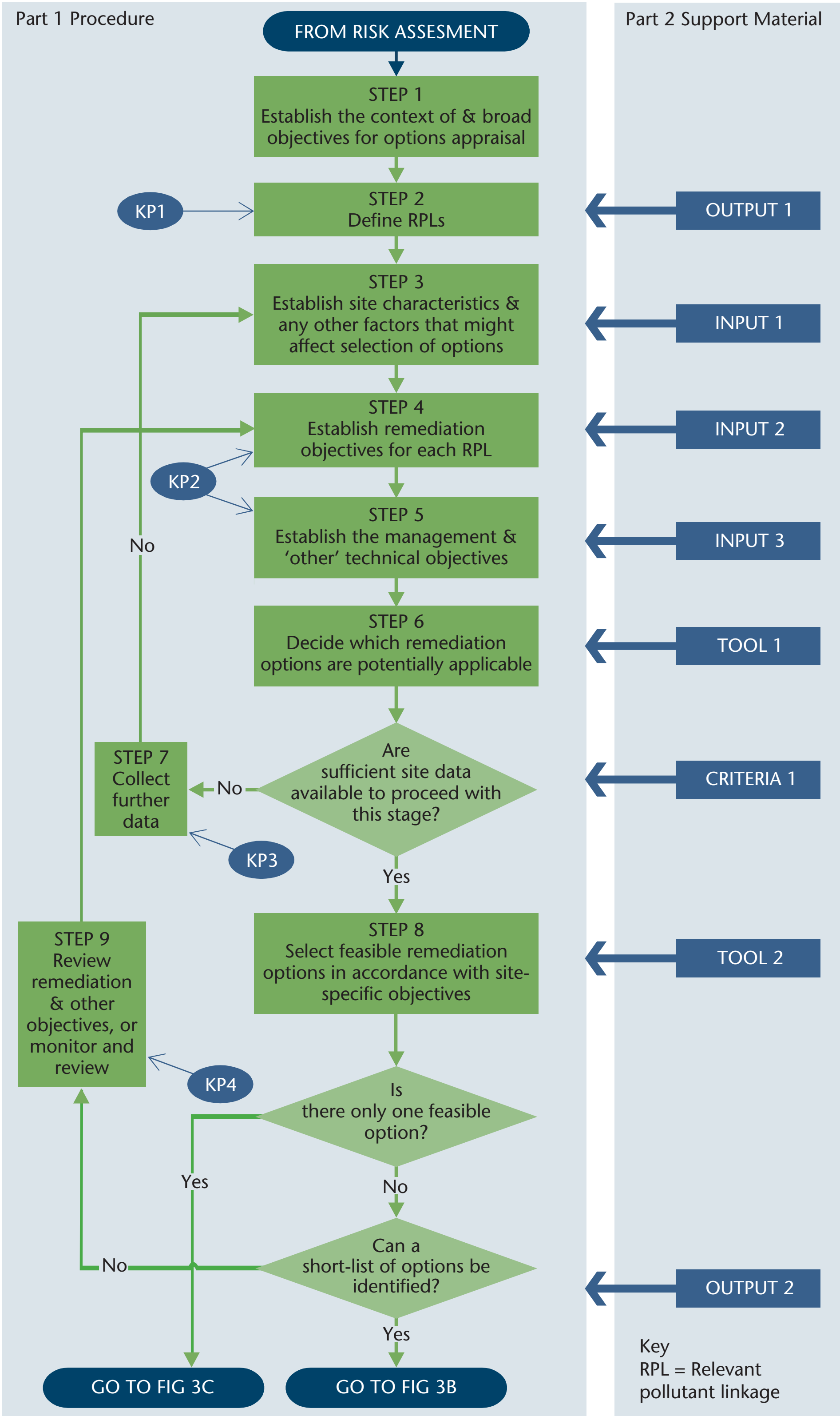


Figure 3A | Identification of feasible Remediation Options

3.3 Detailed evaluation of options

Outline of this stage of Model Procedures

The *purpose* of this stage of options appraisal is to decide, for each relevant pollutant linkage, which of the feasible remediation options is the most appropriate given the specific circumstances of the site.

> The *most appropriate remediation option* will be defined by the evaluation criteria in any particular case, but is likely to be that which is best able to meet site-specific objectives.

It is possible that only one remediation option is required to deal with all the linkages associated with the site. In this case, the remediation strategy is defined by the characteristics of that remediation option alone. In other cases, it may be necessary to combine remediation options to produce a strategy that will address the site as a whole.

At the *beginning* of this stage the appraiser has a shortlist of feasible options for each pollutant linkage, for consideration in more detail.

During this stage the appraiser develops formal criteria to evaluate the options, based on the remediation, management and other technical objectives that have been adopted for the site. To support the evaluation process, the appraiser collects more detailed information on the technical capabilities and limitations of the various shortlisted remediation options. Information on the nature of pollutant linkages and the characteristics of the site is reviewed and, if necessary, supplemented to complete this stage of options appraisal.

The appraiser then carries out a structured analysis of the technical attributes of each option against the formal **evaluation criteria** and estimates the cost involved in implementing the various options. On the basis of the outcome of this evaluation, which involves making judgements about the relative costs and benefits of the different options, the appraiser identifies the most appropriate option for each linkage.

It is important to note that:

- Although the selection of evaluation criteria is a site-specific matter, many criteria will be common to all sites and applications;
- Where it is clear that the remediation strategy is likely to involve more than one remediation option, it will be appropriate at this stage to consider the practicability of combining options.

Decisions

At the *end* of this stage of options appraisal, the appraiser should have decided:

- Which remediation option(s) is the most appropriate for each relevant pollutant linkage;
- Which options (if any) need to be combined.

Outputs

Key outputs from this stage are:

- *Decision Record* – a description of the most appropriate remediation option for each relevant pollutant linkage and which, if any, options may need to be combined;
- An *explanation* of the basis on which particular remediation options have been selected and others rejected.

Technical activities

The steps shown in *Figure 3B* set out the model procedure for carrying out this stage of the options appraisal. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1

Refer back to Stage 1 of options appraisal

KP2

These are based on the remediation objectives, management & 'other' technical objectives adopted for the site

KP3

This could range from further desk study, through further site investigation to laboratory or field-scale trials

KP4

The 'technical' and 'financial' parts of the evaluation should be carried out separately as far as possible.

KP5

For example, some criteria may need to be relaxed to allow identification of a practicable option or the evaluation extended to cover other options

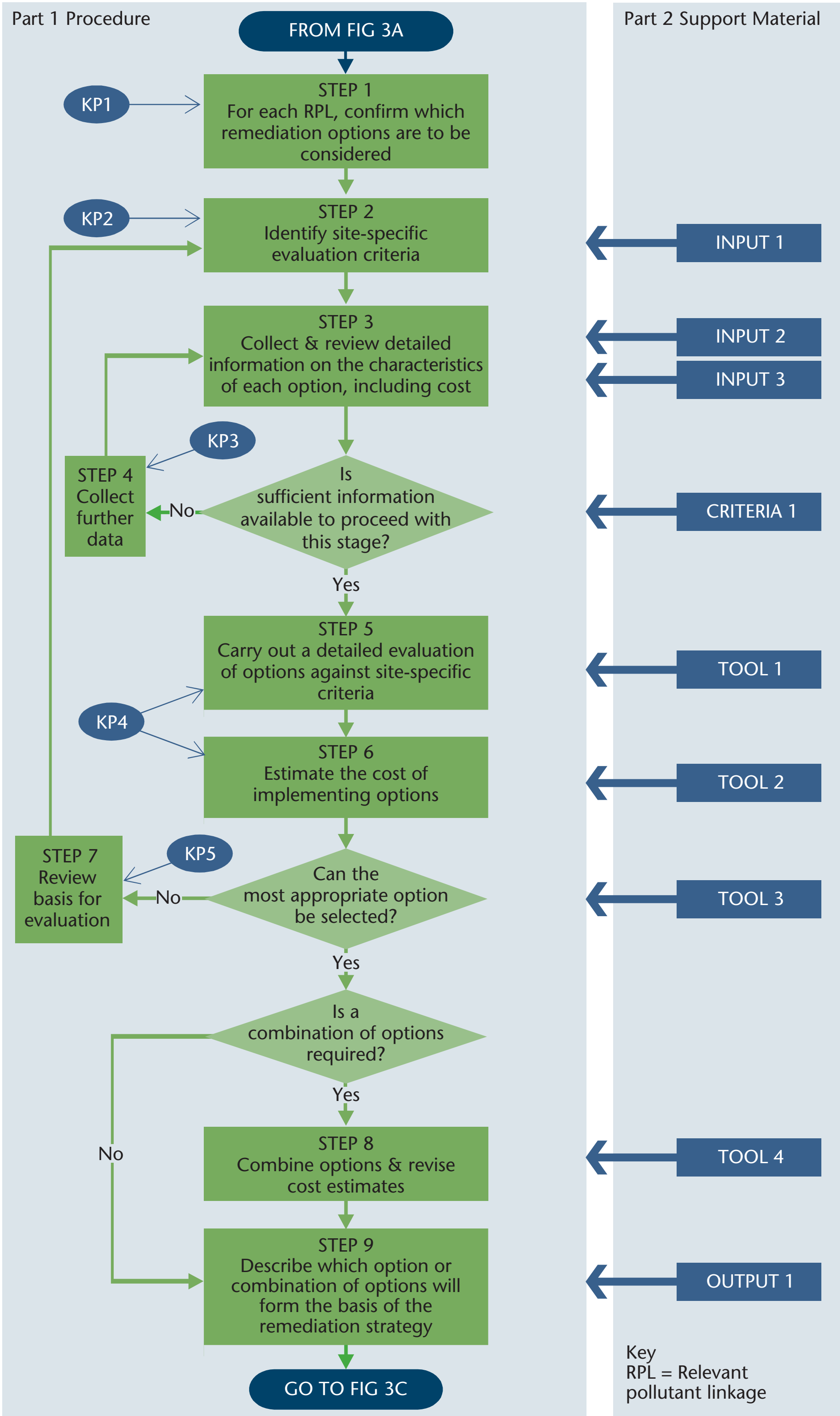


Figure 3B | Detailed Evaluation of Options

3.4 Developing the remediation strategy

Outline of this stage of Model Procedures

The *purpose* of this stage of options appraisal is to develop a remediation strategy capable of practical implementation on the site and to describe in broad terms the characteristics of that strategy.

At the *beginning* of this stage the appraiser has identified which remediation options (whether singly or in combination) are the most appropriate for particular pollutant linkages.

During this stage the appraiser considers in more detail how remediation options are to be put into place in practice. Examples of the practical issues that should be considered at this stage include:

- How the site should be packaged or zoned to accommodate different types or phases of remediation;
- How the remediation strategy is to be verified to demonstrate that site-specific objectives have been met; and
- Whether and how preparatory work (such as baseline monitoring or the creation of access routes) should be factored into the early stages of remediation design.

Appraisers should also be checking that the strategy continues to meet site-specific objectives and is acceptable on cost–benefit grounds. A useful first check is to confirm that the proposed remediation strategy will deal effectively with all of the relevant pollutant linkages identified in the conceptual model defined at the beginning of options appraisal. This should be followed by re-assessment of the combined strategy using the evaluation criteria already established and a finalised cost–benefit analysis based on revised cost estimates.

It is likely that the same site-specific objectives will apply to this stage of options appraisal as applied at stage 2 of this process. However, if it is not possible to achieve practicable implementation or integration of the most appropriate option(s), the appraiser may have to reconsider decisions taken earlier in the process of options appraisal. This might involve a review of the selection of appropriate individual options or, if necessary, adjustment of the site-specific objectives adopted for the site.

Decisions

At the *end* of this stage the appraiser should have decided:

- How, in broad terms, the remediation strategy is to be implemented and what practical issues may be involved.
- Whether the proposed remediation strategy continues to meet all specified remediation, management and other technical objectives and is acceptable on cost–benefit grounds.

Outputs

Key outputs from this stage are:

- *Decision Record* – a description of the remediation strategy and how it meets the objectives for individual pollutant linkages and the site as a whole.
- An *explanation of* how that remediation strategy was developed.

Technical activities

The steps shown in *Figure 3C* set out the model procedure for carrying out this stage of the options appraisal. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1

Key output from Stage 2 of options appraisal

KP2

It is likely that the same site-specific objectives will apply as for Stage 2 of the options appraisal – full details should be kept if objectives have to be changed

KP3

This decision should be based on a re-evaluation (including cost–benefit analysis) of the combined strategy

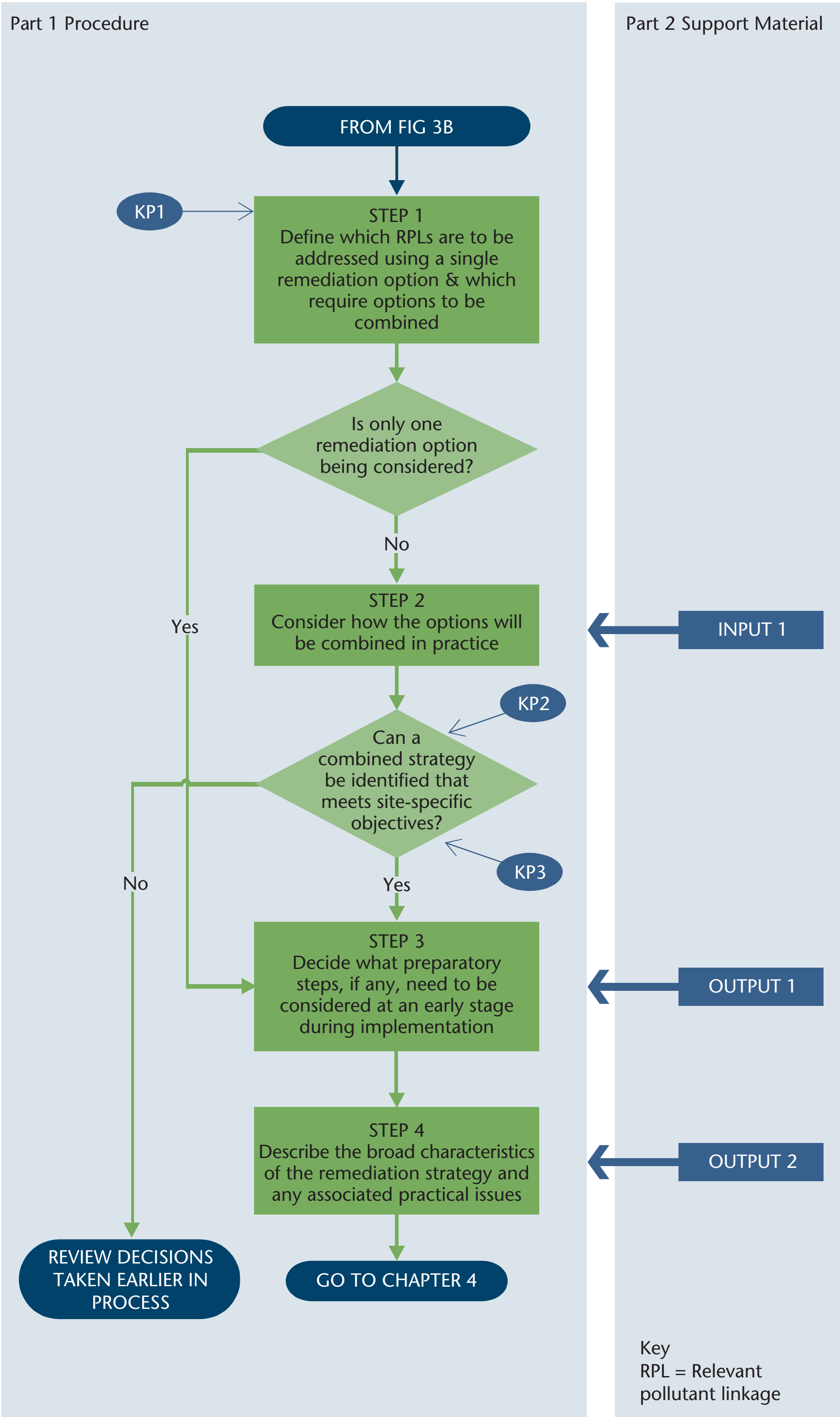


Figure 3C | Developing the Remediation Strategy

4

I

Implementation of the Remediation Strategy

4.1 Overview

The components of risk management described above enable the identification of unacceptable risks and the selection of the most appropriate remediation strategy. The remediation strategy may consist of a number of remediation activities and/or a long-term monitoring programme to manage the relevant pollutant linkages (RPLs) identified within the conceptual model. However, to complete the process of risk management, the remediation strategy needs to be implemented.

This may involve carrying out the remediation as an independent project or combining it with other work planned for the site. For example, if the site is being redeveloped, then the remediation strategy may need to be combined with foundation work or earthworks to achieve a suitable starting point for development.

As a result, remediation may be implemented as a standalone contract or as an integral part of a development-related or other infrastructure project.

An important first task is the development of an **implementation plan**, which deals with all aspects of the design, preparation, implementation, **verification**, and long-term **monitoring and maintenance** of remediation. Implementation of the strategy must be fully recorded, using an appropriate quality management system, such that there is a permanent record (the verification report) of the work done to address the relevant pollutant linkages. Where necessary, remediation needs to be monitored and maintained. Monitoring may be used as a means of demonstrating compliance against the agreed objectives and as an early warning of adverse trends.

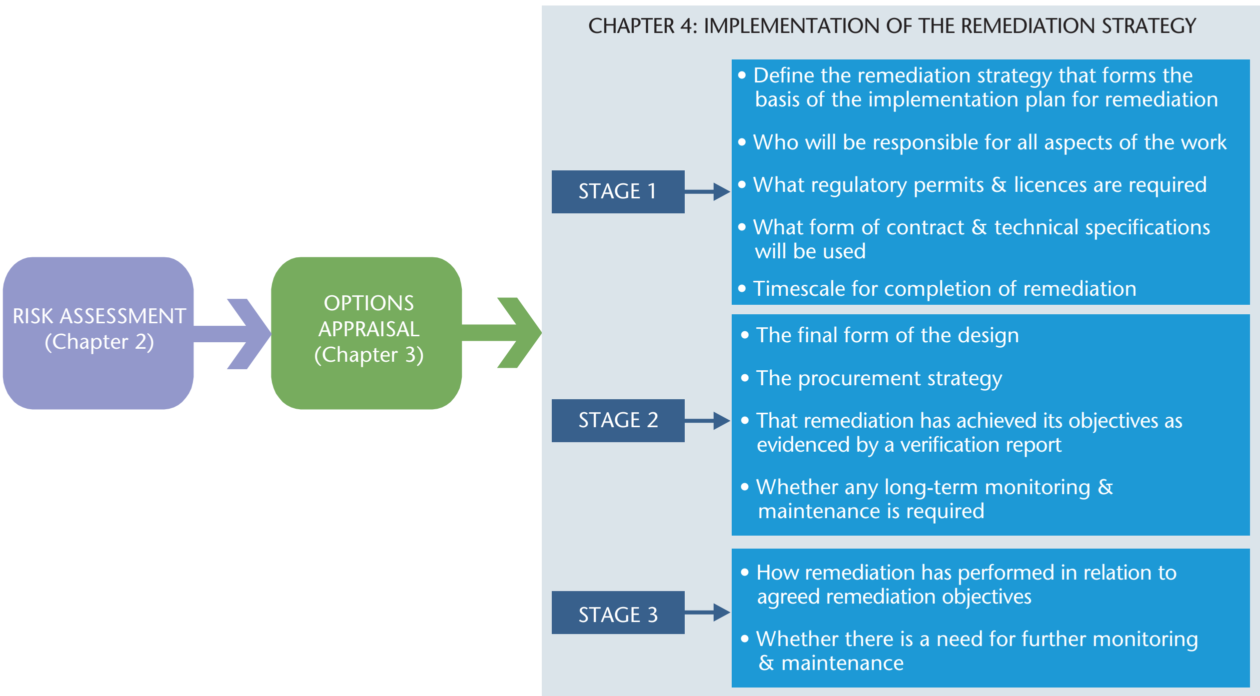


Figure 4.1 | Main Stages & Key Decisions

Depending on the size and timescales of the project, the development of the remediation strategy and implementation plan may be one continuous activity.

There are three main stages in the implementation process:

1 Preparing the implementation plan;

2 Design, implementation and verification of remediation;

3 Long-term monitoring and maintenance.

Figure 4.1 illustrates the key decisions at each stage and the relationship between implementation and the earlier processes of risk assessment and options appraisal.

Particular features of implementation

Overall process

The main aim of implementation is to ensure that remediation achieves the planned objectives efficiently for all RPLs and with appropriate quality assurance.

The process can be built around an implementation plan, which would set out objectives, responsibilities, programme, methods of procurement and site implementation, supervision and verification arrangements and the need for long-term monitoring and maintenance. This is similar to the process of designing, implementing and maintaining construction works – remediation is comparable in broad terms, although many of the specific actions require specialist expertise and there is often a greater need to maintain detailed (in some cases statutory) records and provide quality assurance for civil and regulatory liability and insurance purposes.

Practical factors

To start the process, several practical factors should be considered:

- Is the remediation strategy adequate to deal with all the RPLs within the conceptual model?
- Is the remediation strategy agreed and sufficiently well defined and up-to-date to allow design of the work?
- Are there construction or other works to be carried out on site that must be combined with the remediation activities?
- What regulatory requirements will need to be satisfied to undertake remediation?
- Who will undertake the design role?
- How will remediation be procured?
- Are grants available to off-set the cost of the works?

Developing the design

The design of the actions that comprise the remediation strategy may already have commenced at the options appraisal stage. For example, it may have included some initial design work to establish the feasibility of a particular treatment, the need for preparatory works, such as confirming a suitable Permeable Reactive Barrier (PRB) type and configuration, or the likely balance of materials where an engineering and/or earthworks solution is under consideration. This initial design work is taken forward to the detailed design stage.

Once the scope of work has been defined, design proceeds with the preparation of drawings, specifications and contract documents. The level of detail of design is a function of the procurement method. For example, detailed design of a process may be passed to a specialist. Other elements of design, such as earthworks, may be dealt with as part of a wider development project. Where a design and build route is taken, the initial design work is limited, and may extend only to setting objectives for the final solution. This takes the process back to options appraisal, and may place a responsibility on the design and build contractor to consider all feasible options. Health and safety considerations should also be built into the design in accordance with the duties placed on the designer by the Construction Design and Management (CDM) Regulations.

Options for choosing who will design the remediation activities include:

- *In-house experts*
- *A consultant who will carry out a detailed design and then procure a contractor*
- *A consultant who will carry out a preliminary design and then retain a specialist contractor to complete the design and undertake remediation*
- *A design-and-build contractor who will design and build all aspects*
- *A management contractor who will procure a specialist subcontractor to design and build components of the remediation work*

Whichever route is chosen to implement the design, it is essential that the remediation objectives and assumptions in selecting the most appropriate remediation strategy are passed to those responsible for the final design and other aspects of implementation. Providing formal outputs during the different process stages supports this.

Quality assurance

Quality assurance is an important thread throughout the implementation of the remediation strategy. There are two key features:

- The need to provide an accurate and permanent record of remediation and the standard it has achieved (the **verification report**); and
- Remediation may need maintenance and/or monitoring to achieve or demonstrate on-going effectiveness.

For the first of these it is important that a **verification plan** (see Box) is prepared detailing what is to be measured on site during remediation and how records will be kept and maintained throughout the project for use in the verification report on completion. The plan should also establish the quality standards to be expected from data collected on site or produced by laboratories during remediation. Working within a Quality Management framework will assist in this – it is essential that there is continuity with the earlier stages of the process and with the different phases and components of detailed design.

A **verification plan** is a document that sets out the requirements for gathering data to demonstrate that remediation meets the remediation objectives and remediation criteria. It includes sampling and testing criteria, and identifies all those records that should be retained to demonstrate compliance within the specification (e.g., field monitoring data, analytical data, level surveys above and below capping layers).

A **verification report** provides a complete record of all remediation activities on site and the data collected as identified in the verification plan to support compliance with agreed remediation objectives and criteria. It also includes a description of the work (as-built drawings) and details of any unexpected conditions (e.g., contamination) found during remediation and how they were dealt with.

The timing of production of the verification report will normally be on substantial completion of remediation (ie. implementation and operational stages), although some forms of remediation will require monitoring for some time beyond substantial completion and the results interpreted and reported separately. For example, treatment of groundwater plumes using PRBs will continue to operate for many years after completion of the initial installation. Lines of evidence are established to demonstrate that the PRB is performing as expected and that down-gradient contaminant concentrations are decreasing.

Monitoring reports will be required at appropriate intervals to verify continuing efficiency. Judgements will need to establish when treatment can cease and when the final verification report can be produced.

Where appropriate, a monitoring and maintenance plan needs to be drawn up at the end of the design stage. This needs to be produced at an early stage so that the facility to undertake long-term monitoring can be built into the scheme. It is possible that the remediation will require no long-term monitoring or maintenance, in which case there will be no need for such a plan – this needs to be positively confirmed within the remediation strategy and at the implementation stage.

Note that any site or laboratory-based testing (e.g., to support verification or long-term monitoring) should be carried out in accordance with appropriate quality management systems, such as MCERTS.

Regulatory permits

Some aspects of remediation may require regulatory permits, and these need to be planned at an early stage. For example, if the design includes a treatment scheme that requires a mobile plant licence, the designer needs to take this into account when procuring suitable contractors. If the design requires a waste management site licence or PPC Permit, the designer needs to consult with the client who will become the licence holder, and consider what the likely surrender criteria will be. In some cases remediation may require planning permission.

Typical licences, permissions or permits that may be required include:

- Planning permission
- Waste management licence
    - Mobile plant licence
    - Site licence
- PPC permit
- Abstraction licence
- Groundwater authorisation
- Discharge consent
- Trade effluent consent

Technical aspects

Technical standards for design

The remediation strategy needs to be given substance by translation into detailed design drawings and specifications. The remediation design needs to accord with relevant British Standards and Codes of Practice, and should be checked in accordance with normal quality management procedures. Where elements of the design are passed on to specialist sub-consultants or contractors, the design needs to also be subject to proper checking and quality assurance procedures.

Approvals

Any internal or external approvals required for remediation should ideally be obtained in advance of the work commencing. It is important to be aware that it is not necessarily the role of the regulatory authorities to "approve" remediation, although agreement on what remediation objectives should apply and methods of achieving them may be forthcoming. Gaining agreement on the means of satisfying planning conditions is also to be expected. In the context of Part IIA, close liaison with regulators is needed to ensure that remediation meets the requirements of the legislation.

Getting it right on site

The choice of contractors to carry out remediation needs to take into account their experience of carrying out similar work elsewhere, as well as their staff expertise and organisation.

Where relatively new techniques are being used, it may be the case that a track record of other projects may not exist. This need not be a reason to set aside new methods, although a new technology should not be implemented at full-scale without firstly undertaking site-specific treatability trials and considering the competence of the contractor to carry out the work.

Supervision can be critical for remediation schemes, as the effects of a badly implemented scheme may be less easy to detect subsequently and could have substantial implications. The method of supervision, and the balance of responsibilities between parties on site need to be clearly defined in advance of the works. Responsibilities for protecting specific elements of the work (e.g., protecting pumping or air injection wells against damage by vehicles or vandals) should be clearly defined at the outset.

During remediation, it is important to be able to react to the results of testing or monitoring data in a timely manner. Thus, if decisions on the acceptability of treated soil and/or groundwater can only be made on receipt of laboratory data, the programme needs to allow for obtaining and interpreting that data without delaying the overall progress of the contract. If data show that remediation is not working, alternative solutions or contingency measures may have to be considered.

Verification

Demonstrating the remediation objectives and criteria have been met will be achieved through the verification process. The verification plan sets out the detailed data requirements, including compliance criteria, sampling frequencies and methods, measurement parameters and analytical suites (with limits of detection, bias and precision) necessary to demonstrate that remediation objectives are being met. Setting such requirements effectively establishes '**lines of evidence**' which show that remediation has performed as planned at the time of the implementation, and where appropriate for a specified period thereafter.

The verification report incorporates all site test data and measurements of quality-critical parameters, as well as records of the management of recovery or disposal of materials at the site. This includes materials that have been re-deposited on site, recovered for reuse, taken off site for treatment or imported as backfill.

The report needs to demonstrate that remediation has complied with relevant legislation and that the outcome of the project has met its remediation objectives and criteria.

Where monitoring and/or maintenance of remediation are required, the verification report is only a snapshot in time. In these circumstances the provision of long-term monitoring reports should be viewed as being complementary to the verification report.

Examples of 'lines of evidence'

- Assessment of reaction/degradation rates of contaminants in soil and/or groundwater
- Monitoring operating parameters (e.g. pH, dissolved oxygen, flow rates) and treatment conditions
- Representative measurement of the physical properties (permeability, strength, thickness, level, etc.) of a clay cap or stabilised materials
- Regular monitoring of pollutant concentrations and geochemical properties in groundwater to demonstrate the effectiveness of active treatments and/or natural attenuation

Maintenance
Where remediation includes the construction of permanent structures, these may need maintenance to ensure their continued functionality. Responsibility for and management of this maintenance work will have been identified at the design stage, and may be linked to monitoring the long-term effectiveness of the remediation strategy.

On completion of implementing the remediation strategy, the landowner and any other relevant parties should hold copies of the:

- *Implementation Plan;*
- *Contract documents, as-built drawings and specifications;*
- *Verification Plan;*
- *Monitoring and Maintenance Plan;*
- *Verification Report;*
- *Any Monitoring and Maintenance Reports*
- *Health and Safety file (under CDM Regulations).*

Together these make up a permanent record of the final quality of the land.

Monitoring
The need for long-term monitoring will have been established at the options appraisal stage, as this is a key element in defining the period of time in which a particular remediation option can be effective. For example, in some instances, the future user of a site may not wish to employ a solution that requires long-term monitoring, and will include this as an objective within options appraisal. However, for some situations such monitoring will be unavoidable, for example if a gas-resistant barrier or a permeable reactive barrier have been installed, monitoring over a period of time is needed to ensure effective performance.

Where monitoring has been identified as being necessary, the means to carry this out needs to be built into the remediation design and arrangements made for access to and protection of the compliance installations. A monitoring protocol should be defined, setting out how frequently and over what period of time measurements should be taken. This ongoing responsibility to monitor cannot be divorced from mechanisms to respond if the results of monitoring fail to meet pre-defined compliance criteria. Responses may range from increased frequency of monitoring through to additional remediation. Equally, attainment of remediation objectives over an agreed period of time may be the trigger to cease monitoring activities.

Sources of technical information
Parts 2 and 3 of Model Procedures provide details on a range of technical guidance and tools to assist in the process of implementation of the remediation strategy.

4.2 Preparing the implementation plan

Outline of this stage of Model Procedures

The *purpose* of this stage of implementation is to prepare the implementation plan such that the remediation strategy can be put into place in an effective and orderly manner.

At the *beginning* of this stage there is a defined remediation strategy, which may comprise:

- A single remediation option for one or more pollutant linkages; or
- A combination of options, which may deal with several pollutant linkages.

During this stage the person responsible for implementation of the remediation strategy – the **implementation manager** – is identified.

The implementation manager draws up an implementation plan, which translates the remediation strategy into a clear set of activities, including those concerned with remediation, that will deliver the overall objectives (remediation, management and other technical) agreed for the project, in accordance with client and regulatory requirements. Consultation with relevant parties is part of the development of the plan. Health, safety and environmental protection procedures need to be considered at the outset as an integral part of the work.

The **implementation plan** should set out all aspects of design, preparation, implementation, verification, long-term maintenance and monitoring of remediation. This plan should reflect the complexity of the work and so for simple projects may be a relatively brief document.

Other plans described in this chapter (e.g., verification, monitoring and maintenance plans) may form appendices to the implementation plan.

Decisions

At the *end* of this stage the implementation manager should have a good understanding of the way forward. This should be set out in the implementation plan, which should clearly define:

- The remediation strategy for the RPLs, that formed the basis of the implementation plan;
- Who will undertake each aspect of implementation of the remediation strategy (including verification, monitoring, maintenance, health and safety and environmental protection measures) and what competencies are required;
- What regulatory permits or licences are likely to be required;
- What form of contract and technical specifications will be used to deliver the remediation strategy;
- Timescales for completion of different activities, including any subsequent long-term monitoring activities.

The manager should also confirm that the implementation plan has been agreed with the relevant parties.

Relevant parties that may need to be consulted when completing the **implementation plan** include the:

- *Professional team working on other aspects of the project;*
- *Client (if separate), including the legal team;*
- *Local authority (planning and environmental health);*
- *Environment Agency or SEPA and other regulatory bodies such as HSE, English Nature, English Heritage and equivalent bodies elsewhere in the UK;*
- *Statutory undertakers;*
- *Prospective purchasers;*
- *Prospective insurers and funders;*
- *Neighbours to the site;*
- *Local interest groups.*

Outputs

The key output from this stage is:

- *Decision record* – in this case, this will take the form of an agreed implementation plan that will deliver the project objectives in a timely, safe, cost-effective and quality assured manner.

Technical activities

The steps shown in *Figure 4A* set out the model procedure for carrying out this stage of implementation. The banners to the right show the location of key supporting information in Part 2 of Model Procedures

KEY PROCEDURAL POINTS

KP1

Key output from options appraisal stage

KP2

This step may be used to consider if there are any data gaps that would prevent detailed design of the remediation strategy

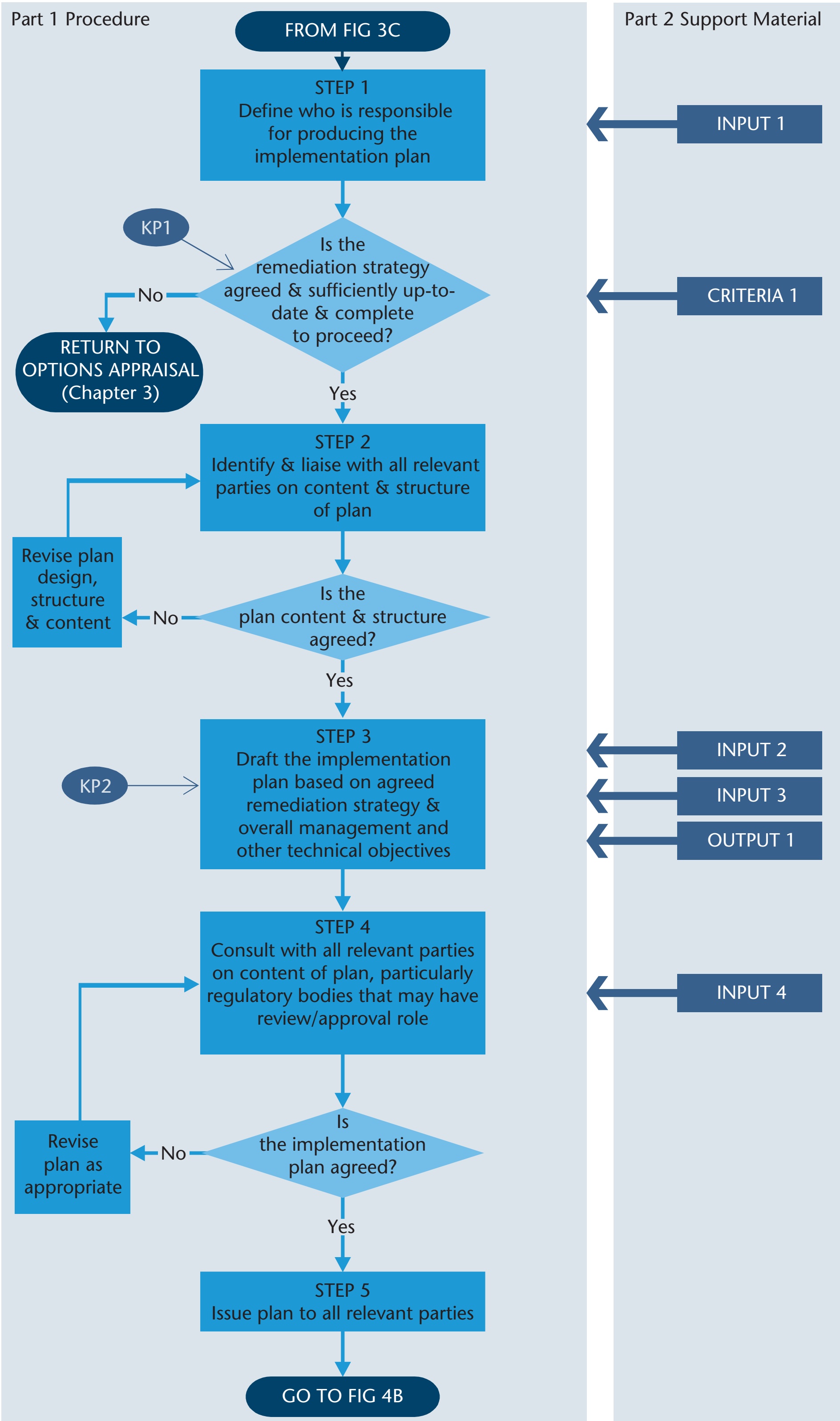


Figure 4A | Preparation of Implementation plan

4.3 Design, implementation and verification

Outline of this stage of Model Procedures

The *purpose* of this stage of implementation is:

- To design the remediation and ensure that the design is fully compatible with other aspects of the project;
- To carry out remediation in a safe and effective manner;
- To verify that the remediation is being undertaken and has been completed in accordance with the design and any subsequent amendments;
- To ensure that the requirements of regulators, insurers and funders are met.

At the *beginning* of this stage the implementation manager has a clearly defined way forward to deliver successful remediation in the form of an implementation plan.

During this stage the implementation manager:

- Identifies and procures suitable professionals to carry out design, supervision and verification duties;
- Ensures any treatability or pilot trials are complete;
- Identifies and procures a planning supervisor in accordance with the CDM regulations;
- Applies for regulatory permits and approvals as appropriate;
- Ensures the design of the remediation is completed, by specialists if necessary;
- Produces drawings, designs, specifications and contract documents;
- Produces a verification plan;
- Produces a monitoring and maintenance plan;
- Identifies and procures suitable contractors to implement remediation;
- Ensures method statements are appropriate, remediation is supervised and verification is undertaken;
- Ensures a verification report is produced.

For all but the smallest projects, to design and undertake remediation is an activity that comes under the control of the Construction Design and Management (CDM) Regulations.

This requires the appointment of a planning supervisor, and identifies specific roles for the client, the designer and the principal contractor to ensure that remediation is designed and undertaken in a safe manner. Users of these Model Procedures should ensure that they are fully aware of the requirements of the CDM Regulations and implement them accordingly.

Decisions

At the *end* of this stage the implementation manager should have established:

- The final form of the design for remediation (based, where appropriate, on the outcome of treatability studies);
- The procurement strategy;
- That remediation has achieved its objectives as evidenced by a verification plan;
- Whether long-term monitoring and maintenance are required.

Outputs

The key outputs from this stage are:

- *Decision records* covering agreement:
    - on the final form of the design,
    - on the procurement strategy,
    - that remediation has achieved its objectives,
    - on the need for long-term monitoring and maintenance;
- Other outputs will be:
    - the final form of the design, including design drawings, specifications and other contract documents,
    - health and safety plans and risk assessments,
    - necessary regulatory permits,
    - contracts for all parties involved,
    - progress reports,
    - verification plan and verification report,
    - monitoring and maintenance plan.

Technical activities

The steps shown in *Figure 4B* set out the model procedure for carrying out this stage of implementation. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1
Step 1 to 7 – finalise design in preparation for procuring remediation

KP2
Ensure verification of remediation is an integral part

KP3
Agree contractor method statements

KP4
Ensure appropriate levels of supervision are provided

KP5
Completion may be absolute (all objectives achieved) or interim (short-term objectives achieved but treatment may continue for some time to come) as identified within the verification plan

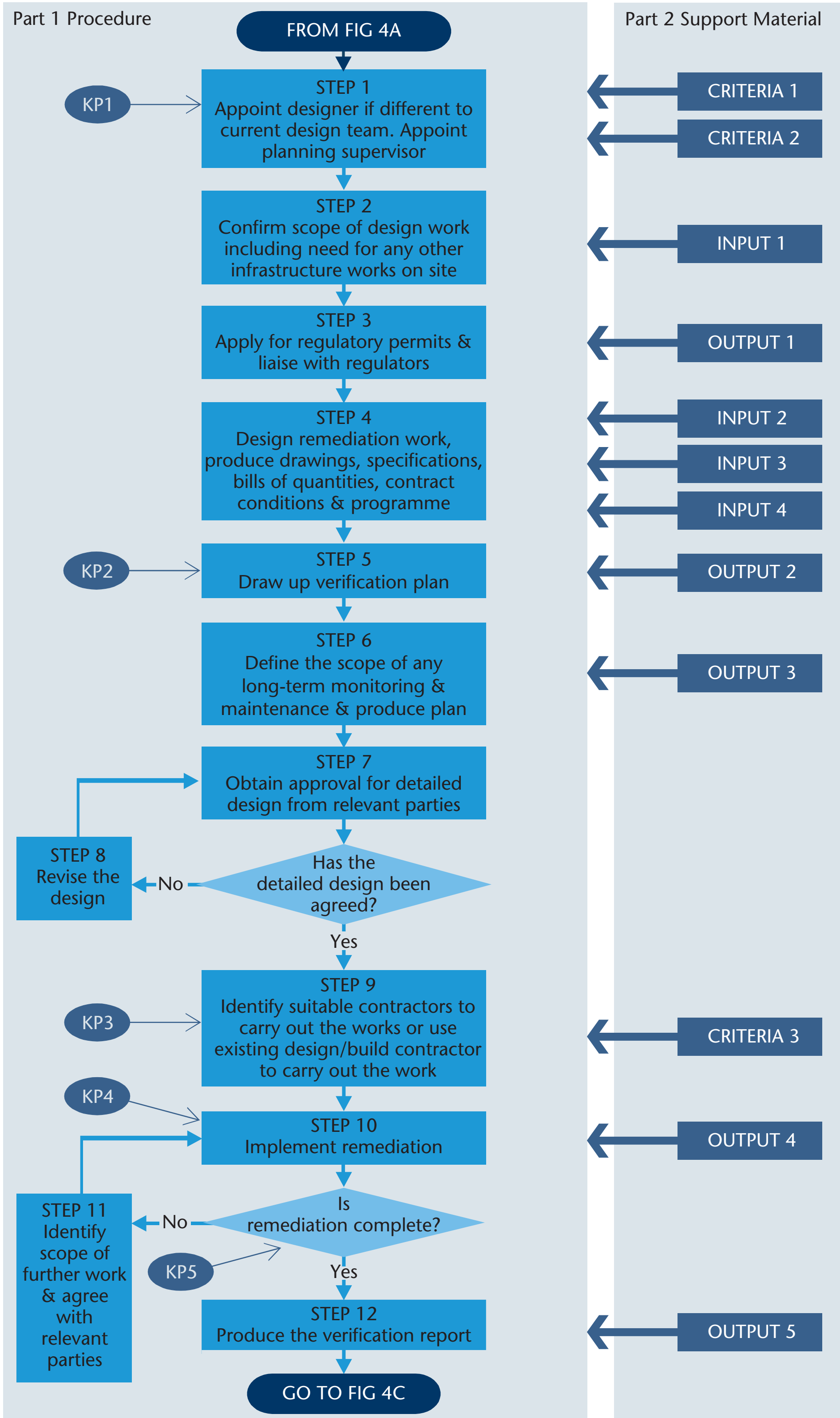


Figure 4B | Design, Implementation & Verification

4.4 Long-term monitoring and maintenance

Outline of this stage of Model Procedures

The *purpose* of this stage of implementation is to monitor the effectiveness of remediation, to confirm predicted behaviour as an early warning of adverse trends, and to maintain remediation to ensure continued functioning and effectiveness in accordance with the original design philosophy.

At the *beginning* of this stage implementation of remediation is complete and a verification report (which may include a monitoring and maintenance plan) is in place.

> If the nature of the remediation is such that monitoring and/or maintenance is not required, then this stage does not apply.
>
> For example, remediation that removed all contaminated soil off site to a treatment facility leaving only unaffected soils on site would need no further monitoring. The effectiveness of the removal would be demonstrated in the verification report. However if, at the same site, there had been historical leaching of contaminants to groundwater, then there may be a need for further monitoring to verify the predicted reduced impacts.

During this stage the implementation manager reviews the monitoring and maintenance plan to ensure its continued validity in the light of any variations during remediation. After the plan is finalised with agreed **monitoring objectives** and **monitoring criteria**, the implementation manager:

- Identifies and procures suitable parties to undertake monitoring and maintenance programmes;
- Ensures that the maintenance programme is carried out and is reported on in an agreed way;
- Ensures reactive maintenance occurs to deal with unexpected events (e.g., vandalism of a gas control system);
- Ensures any identified monitoring work is carried out and is reported on at regular intervals in an agreed way;
- Keeps monitoring and maintenance programmes under review and adjusts them in the light of a comparison between monitoring results and monitoring criteria;
- Ensures copies of all reports and plans are lodged with the relevant parties, along with the verification report.

Decisions

At the *end* of this stage the implementation manager should have decided:

- Whether remediation has performed in accordance with the original or revised remediation design and has met the agreed remediation objectives and criteria;
- Whether there is a need for further monitoring and maintenance work.

Outputs

Key outputs from this stage are:

- *Decision records* covering:
  - agreement that long-term monitoring and maintenance objectives have been met;
  - definition of the need for any further monitoring and maintenance work.
- Other outputs include:
  - monitoring data and reports on compliance with monitoring objectives;
  - maintenance records and reports on any work found necessary for the purposes of repair or upgrade.

Technical activities

The steps shown in *Figure 4C* set out the model procedure for carrying out this stage of implementation. The banners to the right show the location of key supporting information in Part 2 of Model Procedures.

KEY PROCEDURAL POINTS

KP1
Ensure that the plan contains agreed monitoring objectives & criteria

KP2
It may be appropriate to appoint different organisations to deal with monitoring & maintenance

KP3
Ensure that both programmed and reactive maintenance are considered

KP4
Keep the scope of monitoring work under review to ensure it remains valid

KP5
In the event that monitoring objectives have not yet been met, further monitoring and/or other actions should be implemented

KP6 *Copies of reports should be kept by the landowner. Regulators may also require copies*

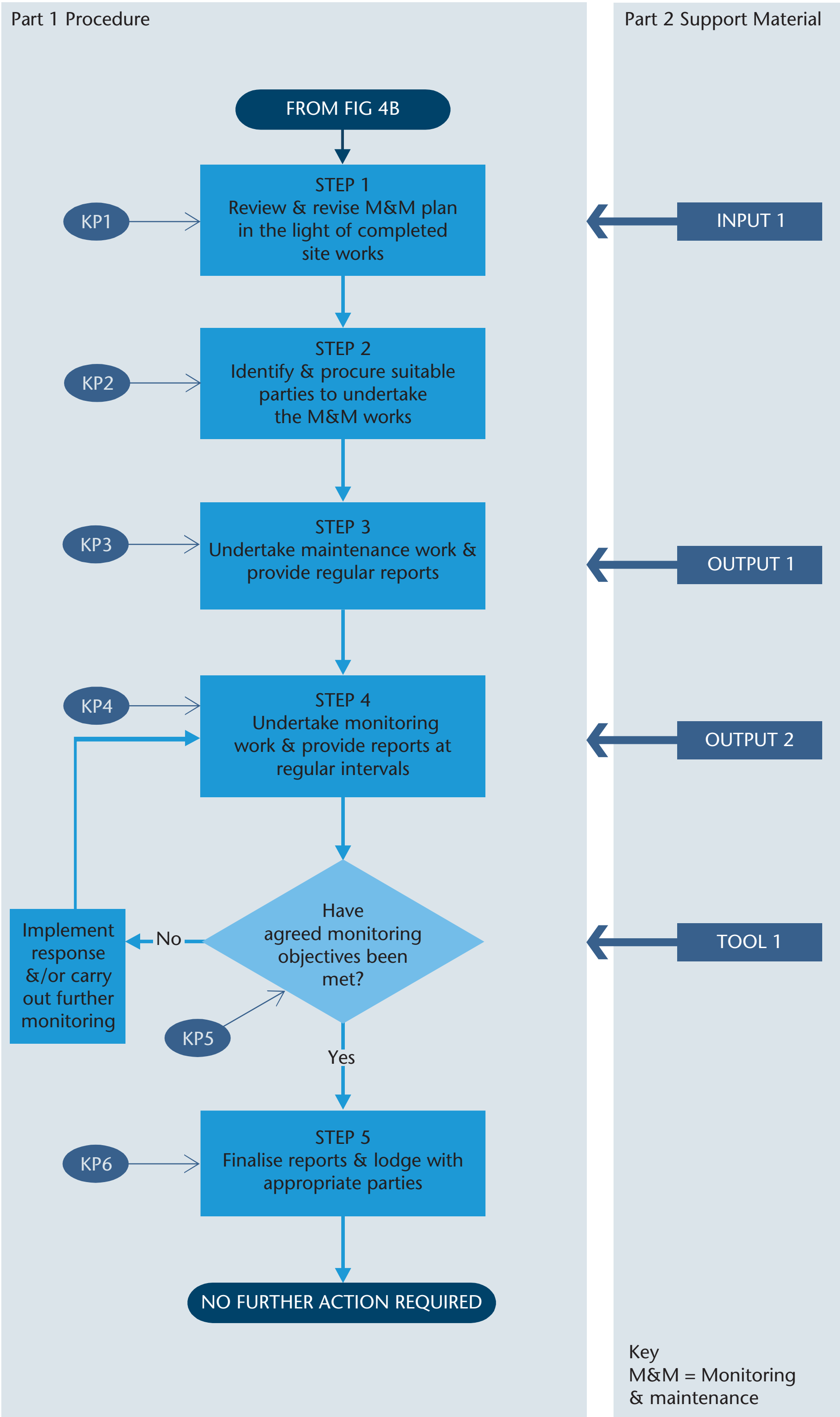


Figure 4C | Long-term Monitoring and Maintenance

5

References and glossary

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- The Scottish Executive Rural Affairs Department, Circular 1/2000. *Environmental Protection Act 1990: Part IIA Contaminated Land*. Available from The Scottish Executive (**www.scotland.gov.uk**).
- *The National Assembly for Wales Guidance on the Remediation of Contaminated Land*, November 2001 **(www.wales.gov.uk/subienvironment/content/guidance/contamland-e.htm)**
- Department of the Environment for Northern Ireland. *The Waste and Contaminated Land (Northern Ireland) Order 1997: Part III*, DoE for Northern Ireland. **(www.ehsni.gov.uk)**

5.2 Glossary

Appraiser A person who carries out the process of options appraisal.

Assessor A person who carries out the process of risk assessment.

Conceptual model A representation of the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.

Contaminant A substance that is in, on or under the land and that has the potential to cause harm or to cause pollution of controlled waters.

Contaminated land Defined in s78A(2) of EPA 1990 as "any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that (a) significant harm is being caused or there is a significant possibility of such harm being caused, or; (b) pollution of controlled waters is being, or is likely to be caused."

Controlled waters Defined by Water Resources Act 1991, Part III, section 104, which includes all groundwater, inland waters, estuaries and coastal water to three nautical miles from the shore.

Decision record A written account of the key decisions made at each stage of the risk management process.

Desk study Interpretation of historical, archival and current information to establish where previous activities were located, and where areas or zones that contain distinct and different types of contamination may be expected to occur, and to understand the environmental setting of the site in terms of pathways and receptors.

Detailed quantitative risk assessment Risk assessment carried out using detailed site-specific information to estimate risk or to develop site-specific assessment criteria.

Detailed site investigation Main stage of intrusive site investigation, which involves the collection and analysis of soil, surface water, groundwater, soil gas and other media as a means of further informing the conceptual model and the risk assessment. This investigation may be undertaken in a single or a number of successive stages.

Durability The extent to which a remediation treatment is likely to be effective in reducing or controlling unacceptable risks to a defined level over a period of time.

Effectiveness The extent to which a remediation treatment successfully reduces or controls unacceptable risks to a defined level.

Environmental impact The effect of remediation treatments on the quality of the environment during or following remediation.

Evaluation criteria (risk assessment) Parameters used to judge whether or not particular harm or pollution is unacceptable.

Evaluation criteria (options appraisal) Formal attributes or factors against which the ability of different remediation options to meet site-specific objectives are measured.

Ex-situ Where contaminated material is removed from the ground prior to above-ground treatment or encapsulation and/or disposal on or off site.

Generic assessment criteria Criteria derived using generic assumptions about the characteristics and behaviour of sources, pathways and receptors. These assumptions will be protective in a range of defined conditions.

Generic quantitative assessment Risk assessment carried out using generic assumptions to estimate risk or to develop generic assessment criteria.

Hazard A property or situation that in particular circumstances could lead to harm or pollution,

Health criteria value Benchmark criteria that represent an assessment of levels of exposure that pose a risk to human health. For example, tolerable daily intake (TDI) and index dose.

Implementation manager A person who is responsible for the implementation of the remediation strategy.

Implementation plan A plan that sets out all aspects of design, preparation, implementation, verification, long-term maintenance and monitoring of the remediation.

In-situ Where contaminated material is treated without prior excavation (of solids) or abstraction (of liquids) from the ground.

Land affected by contamination Land that might have contamination present which may, or may not, meet the statutory definition of contaminated land.

Lines of evidence Collection of data sets for key parameters that support agreed remediation criteria to demonstrate the performance of remediation.

Maintenance Activities carried out to ensure that remediation performs as required over a specified design life.

Management objectives Site-specific objectives defined by stakeholders that relate to regulatory, financial and commercial matters and the desired outcome of remediation.

MCERTS The Monitoring Certification Scheme is a quality assurance scheme for providers of monitoring services, equipment and systems, that is administered by the Environment Agency and accredited by UKAS.

Monitoring A continuous or regular periodic check to determine the ongoing nature and performance of remediation, which includes measurements undertaken for compliance purposes and those undertaken to assess performance.

Monitoring criteria Measures (usually, but not necessarily, expressed in quantitative terms) against which compliance with monitoring objectives will be assessed.

Monitoring objectives Site-specific objectives that define the monitoring programme needed to demonstrate the short- and long-term performance of remediation or to track contaminant behaviour and movement.

Pathway A route or means by which a receptor could be, or is exposed to, or affected by a contaminant.

Pollutant linkage The relationship between a contaminant, pathway and receptor.

Practicability The extent to which it is possible to implement and operate a remediation option or strategy given practical constraints, such as treatment area, access, availability of support services, etc.

Preliminary risk assessment First tier of risk assessment that develops the initial conceptual model of the site and establishes whether or not there are any potentially unacceptable risks.

Quality criteria Measures of the sufficiency, relevance, reliability and transparency of the information and data used for risk management purposes.

Quality management The systematic planning, organisation, control and documentation of projects.

Receptor In general terms, something that could be adversely affected by a contaminant, such as people, an ecological system, property or a water body.

Remediation Action taken to prevent or minimise, or remedy or mitigate the effects of any identified unacceptable risks.

Remediation objective A site-specific objective that relates solely to the reduction or control of the risks associated with one or more pollutant linkages.

Remediation criteria Measures (usually, but not necessarily, expressed in quantitative terms) against which compliance with remediation objectives will be assessed.

Remediation option A means of reducing or controlling the risks associated with a particular pollutant linkage to a defined level.

Remediation strategy A plan that involves one or more remediation options to reduce or control the risks from all the relevant pollutant linkages associated with the site.

Risk A combination of the probability, or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

Risk assessment The formal process of identifying, assessing and evaluating the health and environmental risks that may be associated with a hazard.

Risk estimation Predicting the magnitude and probability of the possible consequences that may arise as a result of a hazard.

Risk evaluation Deciding whether a risk is unacceptable.

Risk management The processes involved in identifying, assessing and determining risks, and the implementation of actions to mitigate the consequences or probabilities of occurrence.

Site reconnaissance A walk-over survey of the site.

Site- specific assessment criteria Values for concentrations of contaminants that have been derived using detailed site-specific information on the characteristics and behaviour of contaminants, pathways and receptors and that correspond to relevant criteria in relation to harm or pollution for deciding whether there is an unacceptable risk.

Stakeholders Individuals or organisations with an interest in the scope, conduct and outcome of a risk management project.

Treatability studies Laboratory or field-scale trials that provide a means of determining the practicability and likely effectiveness of remediation, and estimating the timescales required to achieve the remediation objectives.

Treatment train A sequence of remediation treatments necessary to achieve the standard of remediation when treating contaminated material.

Uncertainty A lack of knowledge about specific factors in a risk or exposure assessment including parameter uncertainty, model uncertainty and scenario uncertainty.

Verification The process of demonstrating that the risk has been reduced to meet remediation criteria and objectives based on a quantitative assessment of remediation performance.

Verification plan A plan that sets out the requirements for gathering data to demonstrate that remediation meets the remediation objectives and criteria.

Verification report Provides a complete record of all remediation activities on site and the data collected as identified in the verification plan to support compliance with agreed remediation objectives and criteria.

Part 2 – Supporting Information

II

Introduction to Part 2

Types of supporting information

Supporting information has been grouped into four categories, each 'badged' with a different symbol to remind the reader what type of information is being presented. Each category (with examples of the type of information that will be presented) is described briefly below.

INPUT	INPUTS are types of information that users need to *carry out* particular steps of the process. For example, information on: • Description of contaminants, pathways and receptors; • General site conditions (e.g., to inform selection of feasible remediation options); • Capabilities and limitations of different remediation methods (e.g., to evaluate their suitability in a particular application); • Factors relevant to establishing particular objectives or parameters (e.g., the procurement policy of an organisation to inform the implementation plan for remediation). At each stage of the process the outputs from previous steps are assumed to be available.
TOOL	TOOLS are specific techniques or methodologies that can help users *to obtain, process or analyse* specific information as part of a process step. Examples include: • Risk assessment models (e.g., for human health, water, ground gases, etc.); • Remediation matrix (e.g. short-listing a range of possible remediation options applicable to particular contaminant and medium combinations).
CRITERIA	CRITERIA are the principles or standards that users require to *reach* a decision at any particular part of the process. Examples include: • A list of receptors for deciding which pollutant linkages cause harm are 'relevant' (i.e., worth considering in more detail) in Part IIA applications (e.g., Table A of Chapter A of the Statutory Guidance); • Soil Guideline Values – to decide whether concentrations of contaminants in soil might pose unacceptable human health risks; • Drinking Water Standards or Environmental Quality Standards (EQS) – to assess risks to the water environment; • Evaluation criteria – to decide (during detailed evaluation) which of a number of remediation options is the most appropriate for a particular linkage given site-specific conditions; • Factors that will decide whether (or not) a proposed implementation plan can be agreed by all relevant parties.

OUTPUT	OUTPUTS are *the results* of the process, set out in written documents. There are three main types: • Decision Record – a summary of the decisions made during and at the end of the process (e.g., there are x, y and z unacceptable risks; three options worth taking forward to detailed evaluation; a workable implementation plan that all parties have agreed to); • A specific output (e.g., a contract specification); • The (technical) account of how the user arrived at a particular decision or other output – the expectation is that these will usually take the form of technical reports or sections of technical reports. For example, users might produce 'an Options Appraisal report' that sets out how decisions were reached on the most appropriate remediation strategy for a site; an output may comprise the findings of a review of an earlier stage of work.

Guide to the arrangement of supporting information

Supporting information is provided for each of the procedural sub-sections set out in Chapters 2 (Risk Assessment), 3 (Option Appraisal) and 4 (Implementation of the Remediation Strategy) of Part 1 of Model Procedures.

The information is presented as a series of information boxes that describe typical or example inputs, tools, criteria or outputs for any particular stage of risk management.

Note that information boxes are current at the time of publication and are examples.

They may not contain all the technical information needed to understand or complete a particular decision or activity. Readers should refer to other sources of information, such as that set out in Part 3 of Model Procedures (the Information Map), for further information and guidance where necessary.

For ease of reference, each batch of supporting information is provided with a contents list and the flowchart for that stage as presented in Part 1 of Model Procedures. To further assist the reader, each information box is coded by means of a page banner carrying the relevant figure reference from Part 1 and a symbol indicating the type of supporting information being provided. A coding key is provided below.

Example	Banner Code	
Input Box supporting Risk Assessment	Preliminary Risk Assessment: **Context and objectives for risk assessment**	**Figure 2A** **INPUT 1** I
Tool Box supporting Risk Assessment	Generic Quantitative Risk Assessment: **Developing generic assessment criteria**	**Figure 2B** **TOOL 1** T
Criteria Box supporting Options Appraisal	Identification of Feasible Remediation Options: **Deciding whether sufficient information is available to select feasible remediation options**	**Figure 3A** **CRITERIA 1** C
Output Box supporting Implementation of the Remediation Strategy	Design, implemenation and verification: **Typical content of a verification plan**	**Figure 4B** **OUTPUT 2** O

1 Supporting Information for Risk Assessment

Flowchart for Preliminary Risk Assessment

KEY PROCEDURAL POINTS

KP1
This will be determined by the overall context for risk management

KP2
This will be largely desk-based research & site reconnaissance

KP3
A typical response would be to return to Step 3

KP4
This decision will depend on the objectives of the risk assessment & priorities for this site in the light of wider priorities

KP5
This will depend both on the overall context & on the types of risk identified

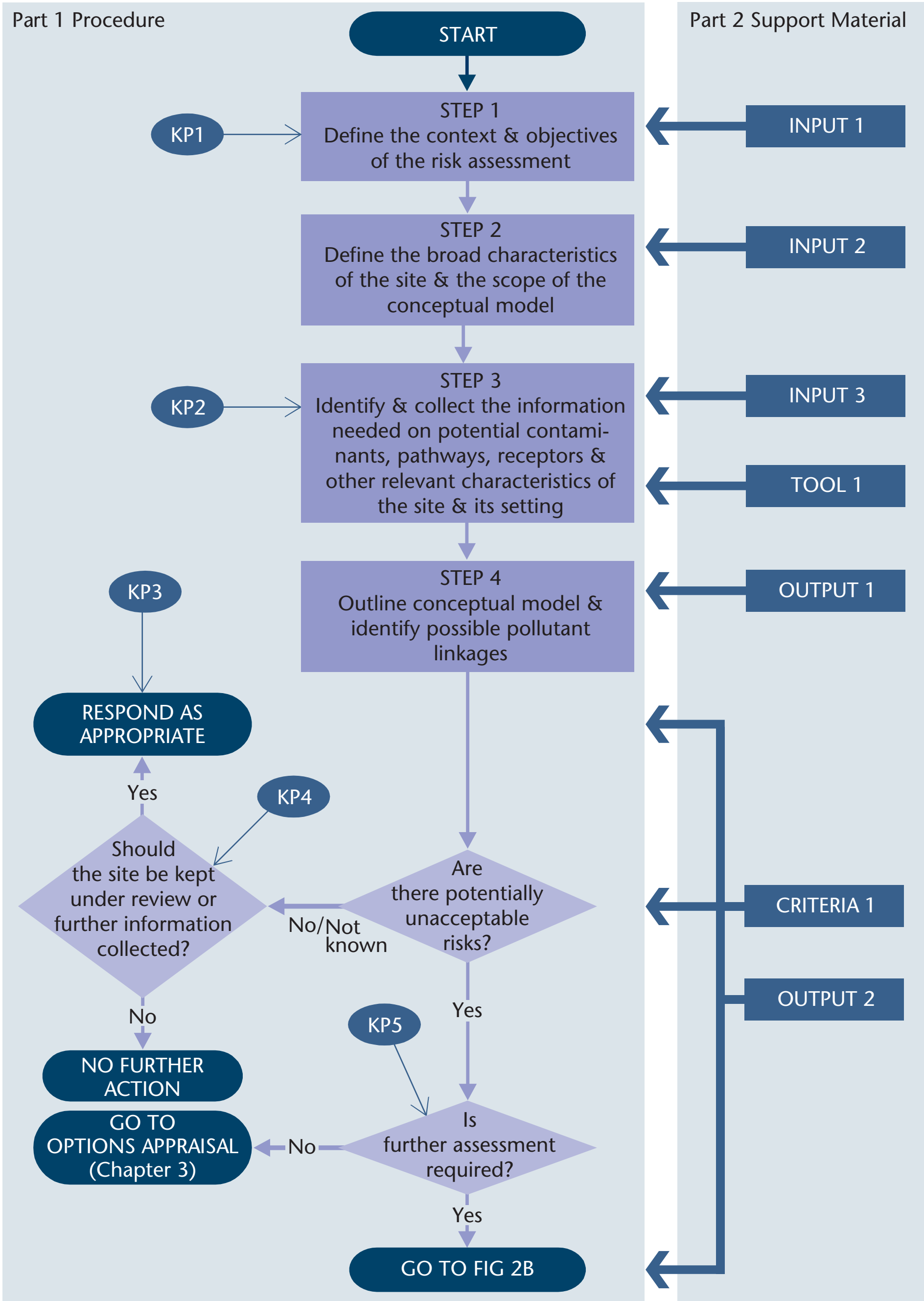

Figure 2A | Preliminary Risk Assessment

Preliminary Risk Assessment (Section 2.2 of Part 1)		
Contents		
INPUTS	INPUT 1	Context and objectives for risk assessment
	INPUT 2	Broad characteristics of site to scope preliminary risk assessment
	INPUT 3	Information needs for preliminary risk assessment
TOOLS	TOOL 1	Methods for collecting information for preliminary risk assessment
CRITERIA	CRITERIA 1	Criteria for deciding if there are potentially unacceptable risks
OUTPUTS	OUTPUT 1	Outline conceptual model
	OUTPUT 2	Preliminary risk assessment report

Preliminary risk assessment:
Context and objectives for risk assessment

Figure 2A
INPUT 1

I

Explanatory Note

The reasons for undertaking the risk assessment will depend not only on the physical context of the site, but also on the management circumstances (see Part 1, Chapter 1).

For example a site that is derelict, but had industrial use, may be assessed to establish whether or not there are risks from contamination. The scope of the risk assessment carried out as part of a planning application to redevelop a site might be wider than one carried out as part of an assessment to determine if the land is contaminated land under Part IIA EPA 1990.

The scope of the assessment will also be different depending on the organisation that commissions the work.

For example, a local authority inspecting the site for Part IIA purposes may have to consider the relative prioritisation of this site compared to others and may be able to carry out only a limited assessment; site owners, however, may decide that they require a definitive picture of a particular site.

The assessor therefore needs to be clear who is commissioning the assessment, for what reasons, and what other possible factors may govern the process.

Key input parameters, with examples, are given below.

Organisations that commission risk assessment, e.g.

- Owner
- Regulatory body
- Purchaser
- Other (e.g., occupier, potential "appropriate person")
- Developer

Possible objectives, e.g.

- to anticipate regulatory action
- to assess the site for Part IIA
- to ensure development is "suitable for use"
- to assess the site in other regulatory contexts
- other
- to inform acquisition, transfer or sale plans
- to support funding decisions
- for valuation purposes
- for insurance purposes

Timescale of assessment, e.g.

- Immediate risks
- Current use of site
- Medium-term risks
- On change of use
- Longer term risks

Level of technical confidence expected, e.g.

- High
- Medium
- Low
- Preliminary or indicative
- Comprehensive

Management constraints, e.g.

- Time
- Budget

Broad characteristics of site to scope preliminary risk assessment

Figure 2A
INPUT 2

I

Explanatory Note

The broad characteristics of the site and its setting will influence the scope of the preliminary risk assessment, and in particular the development of the conceptual model.

> *For example, a coastal site would need consideration of the possible risks to the marine environment, whilst a mining site might require risks to be assessed over a large distance.*

Guidance on development of a conceptual model is provided in Part 3 INFO-RA1.

In all cases, the scope of the preliminary risk assessment should start to address:

- What substances may be present, for example by i*dentifying potential* sources and what *they may have released.*
- The receptors that may be affected, for example: *people, ecosystems, crops, buildings, water, or other receptors* – the particular need to consider any of these may be dictated by the context of the assessment.
- The potential pathways, for example what *type of access* might be possible, what is the *underlying geology.*

Not all the relevant characteristics may be known at the outset of all projects, in which case the scope of the preliminary risk assessment has to be sufficiently broad to address known gaps in information.

The broad characteristics listed here, together with an example of the characteristics and the scope of a conceptual model, give an indication of the level and type of input needed to scope further information needs for the risk assessment.

Context:	*Part IIA assessment*
Broad characteristics:	*Example*
Current use of land:	*Housing*
Access to property:	*Open*
Previous use(s) of land	*Former light industrial use*
Setting:	*Surrounding land also residential* *No information on ecosystems or (preserved) buildings on or close to the site*
Proximity of controlled waters	*Not known*

Scope of conceptual model:

Model will concentrate on receptors (both on and off site) covered by Part IIA and pathways relevant to these receptors. It will consider contaminants relevant to the previous use of the land and any other sources.

Preliminary risk assessment:
Information needs for preliminary risk assessment

Figure 2A
INPUT 3

I

Explanatory Note

The specific information needed for preliminary risk assessment will depend on the context and objectives of the risk assessment, as well as on the broad characteristics of the site.

The checklist below provides an indication of the general type of information that may be required to undertake a preliminary risk assessment. The assessor will need to decide what specific information is needed in any particular case and focus information collection (typically desk study and site reconnaissance) on meeting those particular information needs.

Basic site information

Name of site

Address(es)

Location, including National Grid Reference (NGR)

Broad description of location

Contact points for relevant organisations

Site ownership

Site occupation

Site Plan

Size of site

Land use and setting

Current land use, including ecosystems and other features

Future changes to land use

Access and security, including way-leaves

Services

Description of surrounding land, including key ecological and other receptors etc

Proximity to controlled waters (surface, groundwater and marine) and context of those waters (e.g., use, vulnerability)

Site history and condition

History of the site

- Previous uses
- Authorisations and/or licences, etc.
- Regulatory actions
- Spillages, accidents, emergency response records
- Audit reports

Condition

- Appearance of site, odours, etc.
- Topography and other geotechnical features
- Surface features (e.g., vegetation)
- Geological setting
- Structures and services
- Existing information on chemical and biological conditions
- Details of any remediation
- Other influences (e.g., natural contamination, condition of surrounding land)

Hydrogeological and hydrological information

- Water quality information
- Information on characteristics (e.g., flow direction)

Methods for collecting information for preliminary risk assessment

Figure 2A
TOOL 1

T

Explanatory Note

The basic methods for collecting information for preliminary risk assessment are:

- A desk study;
- A site reconnaissance.

A range of guidance that describes how to carry these out is available – full details of relevant sources and a brief description of each are provided in Part 3 of the Model Procedures.

The information may also be already available, at least in part. For example, the information in the checklist above may be contained in a Land Condition Record (LCR) prepared for the site (for further information on LCRs, see **www.silc.org.uk**).

Methods for collecting information

See Part 3

INFO-RA1 Key information sources: Preliminary risk assessment

INFO-SC1 Key information sources: Site characterisation – general

Criteria for deciding if there are potentially unacceptable risks

Figure 2A
CRITERIA 1

C

Explanatory Note

The criteria for deciding if there are potentially unacceptable risks depend on the site and the context of the risk assessment. The starting point for establishing the criteria will be the objectives and the scope of the risk assessment.

Criteria are then specific to the particular types of risks associated with the site. *For example the criteria for a preliminary risk assessment for Part IIA will focus on whether or not specific receptors may be affected.*

An indication should be given of the acceptable level of uncertainty around the decision. *For example: corporate policy might require a high level of confidence that potential environmental risk exposure has been identified.*

The assessor will therefore have to identify the appropriate criteria for the particular preliminary risk assessment. The examples below indicate typical criteria in different contexts.

Context	Substance	Receptor	Pathways	Criteria for decision
Part IIA	*Oils*	*River*	*Drainage*	*Any indication that oil might be reaching a river*
Change of use	*Cadmium*	*New residents*	*Any*	*Any indication that intake could exceed Tolerable Daily Intakes*
Sale of land	*Any*	*Those in Part IIA*	*Any*	*Any indication that site could fall within the Part IIA definition of contaminated land*

Preliminary risk assessment:
Outline conceptual model

Figure 2A
OUTPUT 1

O

Explanatory Note

A conceptual model of a site can be presented in a number of different ways. The aim of them all is to present the characteristics of the site, provide a systematic indication of what risks may result and enable uncertainties and further assessment needs or other actions to be identified.

Guidance on development of a conceptual model is provided in Part 3 INFO-RA1. The main approaches – which may be combined – are:

- A text description of the site;
- A tabular or matrix description;
- A drawing or other diagrammatic illustration.

The simple example below is used throughout the risk assessment and options appraisal sections of the Model Procedures and shows a brief text description with a table presentation of pollutant linkages. At each stage of risk assessment the conceptual model is developed further.

(Note that the example is for illustrative purposes only: not all possible pollutant linkages are listed and the model does not provide information, for example, on different locations of contaminants that may lead to different pollutant linkages.)

Description of site

The site (≈ 0.5 hectares) was formerly occupied by an engineering workshop. It is currently being considered for redevelopment for residential purposes – all of the proposed dwellings will have private gardens. The site is located in an urban area with established residential properties on all boundaries.

The site is generally level. The site geology is made ground overlying sands and gravels overlying marl. A river is located approximately 150 m to the east of the site.

Possible pollutant linkages

Contaminant	***Pathway(s)***	***Receptor***
Metals A, B, C	• *Ingestion, inhalation, direct contact*	• *Future residents, site workers, (possibly) neighbours*
	• *Consumption of contaminated vegetables*	• *Future residents*
Semi-volatile, non-halogenated hydrocarbons D, E, F	• *Dermal contact* • *Migration through made ground* • *Migration through gravels*	• *Future residents* • *Groundwater in gravel* • *River*
Volatile halogenated hydrocarbons X, Y, Z	• *Migration into buildings* • *Migration through made ground* • *Migration through gravels*	• *Future residents* • *Groundwater in gravel* • *River*

II

Preliminary risk assessment:
Preliminary risk assessment report

Figure 2A
OUTPUT 2

O

Site referencing information

Name of site	Site ownership
Address(es)	Site occupation
Location, including NGR	Plan and size of site

Decision Record

Summary of site context and objectives of preliminary risk assessment

Summary of context of risk assessment and objectives of risk assessment, *for example preliminary risk assessment commissioned by owner as part of development proposals to establish requirements for more detailed investigation.*

Summary of site characteristics and setting; *for example site is currently vacant within an industrial estate, has a history of industrial use and is located on a minor aquifer and adjacent to a river.*

Outline conceptual model and possible pollutant linkages

Text, drawing, etc., of conceptual model showing characteristics of site and possible pollutant linkages.

Potentially unacceptable risks

Indication, including degree of confidence, of which linkages may give rise to unacceptable risks and which linkages are not considered to present potential risks, or which require further information in the context of the preliminary risk assessment.

Criteria used to make the decision.

Proposed next steps

What is to be done, by whom and over what timescale; *for example, the site is to be kept under review by local authority as part of its 5 year inspection strategy.*

Explanation of, and supporting information for, preliminary risk assessment

Context and objectives of risk assessment

Characteristics of site and scope of conceptual model development

Methods used for information collection

Information available:

Basic site information, site history and condition, land use and setting

Basis of development of conceptual model:

Characteristics of site

Potential contaminant sources, potential pathways and receptors potentially at risk

Evaluation of potential risks:

Criteria used

Results of evaluation, including uncertainty and information gaps

Description and justification of next steps

Flowchart for Generic Quantitative Risk Assessment (Section 2.2 of Part 1)

KEY PROCEDURAL POINTS

KP1

This may require updating the output from the preliminary risk assessment stage

KP2

These will depend on the management context of the site

KP3

This requires separate consideration of each potential pollutant linkage

KP4

In some cases it may be more cost effective to move straight to options appraisal, but this will mean that risk assessment objectives will need to be amended

KP5

This applies for each pollutant linkage

KP6

Depending on the risk assessment context, options might include:

- *Keep the assessment under review*
- *Collect further information*
- *Carry out detailed quantitative risk assessment*
- *Move to the risk management stage*

KP6

This will depend on the context of the risk assessment & site circumstances. For example, it may be necessary to collect more information to refine this stage of assessment or to carry out detailed quantitative risk assessment on the site as a whole or on particular linkages

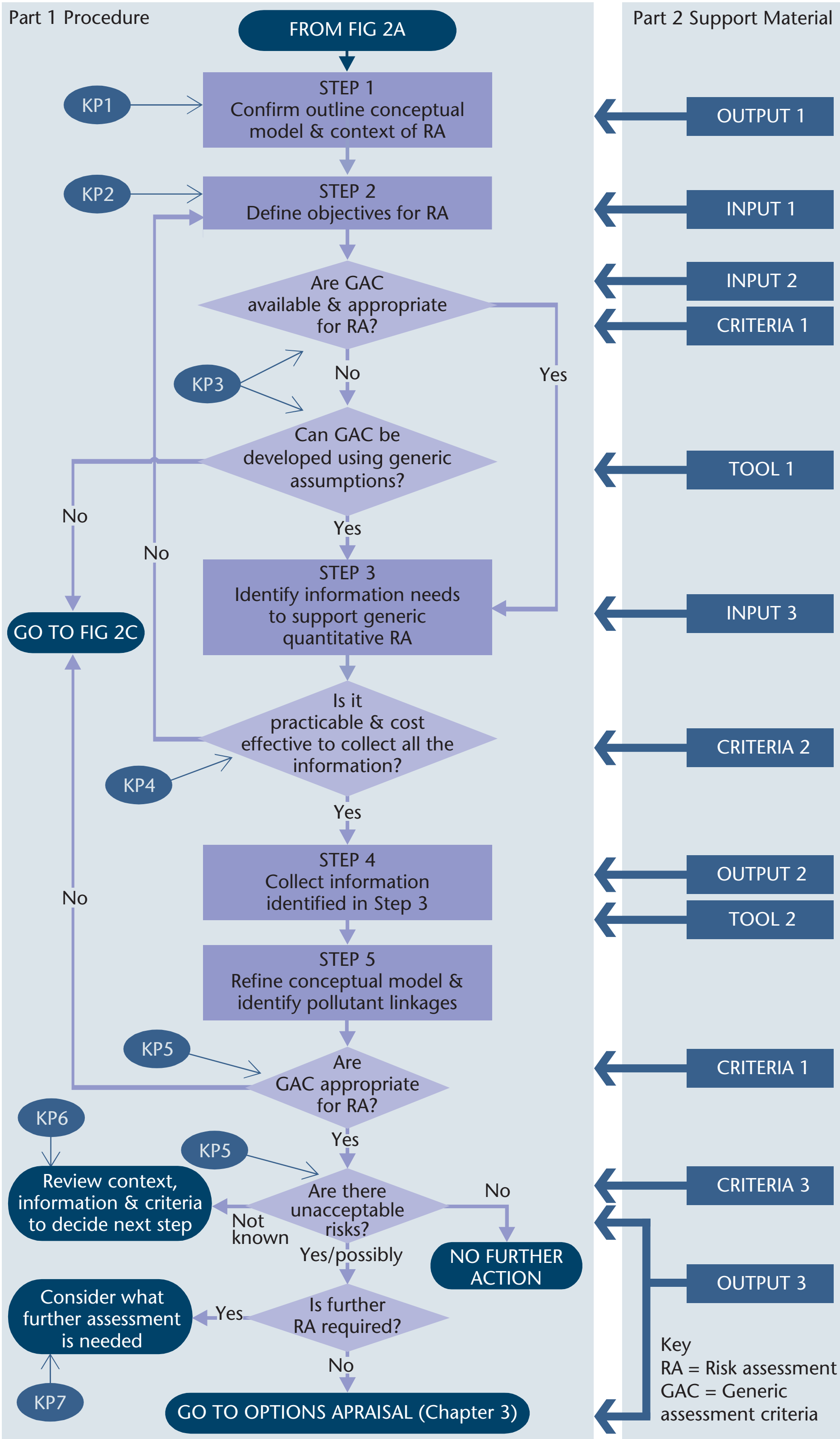

Figure 2B | Generic Quantitative Risk Assessment

Generic Quantitative Risk Assessment (Section 2.3 of Part 1)

Contents

INPUTS	INPUT 1	Factors to be taken into account when defining objectives for quantitative risk assessment
	INPUT 2	Generic assessment criteria
	INPUT 3	Information requirements to support generic quantitative risk assessment
TOOLS	TOOL 1	Developing generic assessment criteria
	TOOL 2	Methods for collecting information
CRITERIA	CRITERIA 1	Deciding if generic assessment criteria are appropriate for use
	CRITERIA 2	Deciding the scope of investigation to support generic quantitative risk assessment
	CRITERIA 3	Quality issues to be considered when assessing site investigation information
OUTPUTS	OUTPUT 1	Relevant pollutant linkages and basis for quantitative risk assessment
	OUTPUT 2	Site investigation report
	OUTPUT 3	Risk assessment report

Generic Quantitative Risk Assessment:
Factors to be taken into account when defining objectives for quantitative risk assessment

Figure 2B
INPUT 1

I

Explanatory Note

The factors to be taken into account build on the context and objectives for the risk assessment from the preliminary risk assessment stage. However, as the next stage of risk assessment is likely to involve collection and assessment of detailed information, it is essential at the outset to refine the objectives for the risk assessment to focus the information collection efficiently.

Factors to be taken into account will cover a broad range of technical and non-technical issues. The following list of parameters gives an indication of what could be considered at this stage to focus the scope of the detailed risk assessment and assist in decision making.

Factors

Technical	Complexity of site and ground conditions
	Nature of pollutant linkages
	Synergistic and cumulative factors
	Timeframe for risk assessment
	Potential changes in site circumstances
	Handling data uncertainty
Management	Management aspirations
	Regulatory requirements
	Need for consultation and agreement with stakeholders
	Constraints on time and/or budget
	Risk communication
Social	Factors of safety required
	Degree of confidence required
	Independence of data and evaluation
	Public perception

Explanatory Note

Generic assessment criteria have developed over a number of years in different applications relevant to land contamination. They can include criteria that relate to the concentrations of substances in air and water as well as in soil. The main purpose of the use of generic assessment criteria is to simplify the assessment of risk and provide an element of standardisation of approach by different parties or on different sites.

Generic assessment criteria may range from highly conservative screening values that apply to a range of sites, conditions and exposure scenarios, to criteria based on a more narrowly focused set of assumptions and other parameters that are appropriate to a limited, but still generic, category of sites, conditions and exposure scenarios.

Soil is a very complex medium, which, coupled with the complexity of ground conditions, the way in which land is used and the way in which contamination interacts with and affects people and the environment, means that generic assessment criteria for all substances in all circumstances are not available.

Even where generic assessment criteria are available, they may not be suitable for the particular pollutant linkage or risk assessment context:

- Generic assessment criteria may not match the underlying criteria for unacceptable risk, or the context of the risk assessment, or the particular characteristics or behaviour of the contaminants, pathways or receptors.
- Some generic assessment criteria have been developed using highly conservative assumptions to screen out sites that definitely would not present a problem – other sites may fail the criteria but this may not necessarily represent an unacceptable risk in the particular management context in which decisions have to be made at this tier of risk assessment.
- Other generic assessment criteria may include conservative assumptions that are not appropriate for the characteristics of the site or the pollutant linkage in question – again, these may not necessarily represent an unacceptable risk.
- The focus of the generic assessment criteria may have been on representing specific, but common, circumstances, so that assessment using these criteria may represent a fairly narrow judgement about the actual risks presented by the site.

There are two stages in establishing whether generic assessment criteria and assumptions are appropriate for a particular site:

- Identifying possible criteria – possible sources of UK criteria are listed below;
- Deciding whether they are appropriate – factors to consider are presented in Figure 2B CRITERIA 1.

Examples of generic assessment criteria for assessing risks to human health (See Part 3: INFO-RA2-2)

Contaminants in soil	
UK Soil guideline values	DEFRA/Environment Agency, *Guideline Values for Contaminants in Soils*, SGV series, 2002
Contaminants in air	
Air quality criteria	*Air Quality Limit Values Regulations* for ambient air quality criteria
	See Health and Safety Executive, *Occupational Exposure Limits* EH/40 (updated annually) for occupational exposure applications
Contaminants in water	
Drinking water standards	Environment Agency, *Environment Agency Technical Guidance to Third Parties on Pollution of Controlled Waters for Part IIA of the EPA 1990*, 2002

Examples of generic assessment criteria for assessing risks to the water environment (See Part 3: INFO-RA2-3)

Environmental quality standards	Environment Agency, *Environment Agency Technical Guidance to Third Parties on Pollution of Controlled Waters for Part IIA of the EPA 1990, 2002*
Drinking water standards	

Examples of generic assessment criteria for assessing risks to the built environment (See Part 3: INFO-RA2-4)

Hazardous gases	CIRIA, *Protecting Development from Methane*, R149, 1995
	The Building Regulations 2000, Site Preparation and Resistance to Contaminants and Moisture, Approved Document C, 2004 edition
Substances hazardous to buildings, building materials and services	BRE, *Performance of Building Materials in Contaminated Land*, BR255, 1994
	Environment Agency, *Risks of Contaminated Land to Buildings, Building Materials and Services : A Literature Review*, Technical Report P331, 2000,
	BRE, *Concrete in Aggressive Ground*, Special Digest 1, 2003

Examples of generic assessment criteria for assessing risks to ecosystems, animals, crops, etc. (See Part 3: INFO-RA2-5)

Ecological guideline values or benchmarks (e.g., Predicted No Effect Concentrations, PNECs)	ICRCL, *The Restoration and Aftercare of Metalliferous Mining Sites for Pasture and Grazing*, ICRCL 70/90, 1990
	Environment Agency, *A Review of Soil Screening Values for use in Ecological Risk Assessment*, R&D Technical Report, P5-091/TR, 2004
	Environment Agency, *Ecological Risk Assessment* (Consultation draft), R&D Technical Report P5-069/TR1, 2003
Application criteria for sewage sludge to land	DoE, *Code of Practice for Agricultural Use of Sewage Sludge*, 1996

Generic Quantitative Risk Assessment:
Information requirements to support generic quantitative risk assessment

Figure 2B
INPUT 3

I

Explanatory Note

The information requirements for generic quantitative risk assessment will depend on:

- The substances being assessed, *for example the information for assessing risks from methane will be different to that for assessing risks from mercury*
- The receptors being considered, *for example, whether it is people, ecosystems, crops, water or buildings*
- The complexity of the site, particularly if there are *mixtures of contaminants*

For each site, some of the specific information needs will be identified from the relevant guidance on the development or use of particular generic assessment criteria. The information should also aim to improve understanding of the knowledge of the characteristics of the site to refine the conceptual model. Basic types of information likely to be required are indicated below.

The information collected should be sufficient to support the use of generic assessment criteria, where these are identified as appropriate for some or all pollutant linkages. Some of the information may be similar to that needed for more detailed assessment, for example for linkages for which generic assessment criteria are not available, and the assessor should consider what information needs can be combined at this stage for efficient site investigation.

Assessors should also refer to Figure 2B – CRITERIA 3 in relation to the quality of information required.

Information about the contaminant, e.g.

- *Lateral and vertical extent*
- *Chemical form*
- *Concentrations*
- *Potential for leaching and migration*

Information about the ground, e.g.

- *General type of ground*
- *Stratigraphy*
- *pH, soil organic matter content and other soil parameters relevant to the use of generic assessment criteria*

Information about the receptors, e.g.

- *Relationship to site – distance, contact, etc.*
- *Particular type*
- *Vulnerability to particular substances*
- *Behaviour or role*
- *Existing condition and history*

Information about the pathways, e.g.

- *Number and extent*
- Type
- Location
- Nature and condition

Other site conditions, e.g.

- *Atmospheric conditions*
- *Potential for flooding*
- *Any remediation carried out*
- *Weather patterns, tidal impacts, etc.*
- *Structures and buried services*

Explanatory Note

In some cases, it may be possible to develop generic assessment criteria for assessing the risk. This will be based on conservative assumptions about the behaviour of the contaminant, pathway or receptor.

This is the basis behind the derivation of authoritative generic assessment criteria at the national or organisational level, for example the soil guideline values derived from the CLEA model for contaminants in soils in the UK context. Although the derivation of such generic assessment criteria requires care and specialist knowledge, some of the models and formulae used to predict risk can be employed in a relatively simple way to derive generic assessment criteria using generic assumptions about the characteristics of the site and other relevant parameters.

Examples of models that may be used are listed below.

Examples of models that may be used (see also the Environment Agency Fact Sheets on risk assessment tools in Part 3 – INFO-RA2-1)

Human Health (See Part 3: INFO-RA2-2)

CLEA	DEFRA/Environment Agency, *The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms*, CLR 10, 2002
SNIFFER Method	SNIFFER, SEPA, Environment Agency, *Method for Deriving Site-Specific Human Health Assessment Criteria for Contaminants in Soils*, LQ01, 2003

Water Environment (See Part 3: INFO-RA2-3)

Environment Agency R&D Publication 20	Environment Agency, *Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources*, R&D Publication 20,1999
	Environment Agency, *Remedial Targets Worksheet v2.2a: User Manual*. NGWCLC report NC/99/11, 2001
CONSIM	Environment Agency, *Contamination Impacts on Groundwater: Simulation by Monte Carlo Method*, ConSim release 2, Environment Agency R&D Publication 132, 2003

Hazardous Ground Gases (See Part 3: INFO-RA2-4)

CIRIA, *Protecting Development from Methane*, R149, 1995

Wilson, S.A. & Card, G.B, *Reliability and Risk in Gas Protection Design*, Ground Engineering, February 1999 *and* News Section of Ground Engineering, March 1999 (this contains points of clarification that must be read in conjunction with the February paper)

DETR/Partners in Technology, *Passive Venting of Soil Gases Beneath Buildings*, Volume 1(Guide for Design) and Volume 2 (Computational Fluid Dynamics Modelling: Example Output), DETR, 1997

British Standards Institution, *Ventilation Principles and Designing for Natural Ventilation*, Code of Practice, BS 5925:1991

Generic Quantitative Risk Assessment:
Methods for collecting information

Figure 2B
TOOL 2

T

Explanatory Note

The basic method for collecting information for detailed risk assessment is to carry out intrusive investigations on the site and its surroundings.

A range of guidance that describes appropriate techniques and quality assurance for this type of investigation is available – full details of relevant sources and a brief description of each are provided in Part 3 of the Model Procedures:

Methods for collecting information

INFO – SC1	Key information sources: Site characterisation – general
INFO – SC2	Key information sources: Site characterisation – sampling design
INFO – SC3	Key information sources: Site characterisation – laboratory analysis
INFO – PM1	Key information sources: Project Management – guidance specific to a particular industrial or commercial sector
INFO – PM2	Key information sources: Project Management – health and safety and quality management

Explanatory Note

Assessors should select and interpret generic assessment criteria with care. There are two main aspects to the selection of appropriate criteria – the relevance to the technical context and the relevance to the specific context and objectives of the decision. The criteria should also be transparent.

A number of different criteria are potentially available – further details and examples are given in Figure 2B – INPUT 2

Relevance to the technical context

- The generic assessment criteria should either have been designed specifically to assess risks from land contamination, or be suitably adapted for this purpose.
- The generic assessment criteria should be applicable to the particular characteristics of the site and the pollutant linkages. They should be related to the:
  - Form of contaminant under consideration;
  - Relevant media (e.g., soil, sediments, water, vapour and/or dusts) and other parameters, (e.g., soil type, pH);
  - Receptor under consideration, and within that the:
    - species or special feature most likely to be at risk or an appropriate indicator species;
    - behaviour, vulnerability or use of that receptor;
  - Pathways, and specifically;
    - the nature, (e.g., ingestion, direct contact, migration, leaching, etc.),
    - the characteristics (e.g., the type of access or ground conditions),
    - whether this is short or long term.

Relevance to the decision

The criteria must be relevant to:

- The context of the decision (e.g., for Part IIA EPA 1990 do the criteria link to Table B of Chapter A of the statutory guidance (DETR Circular 02/2000));
- The objectives of the decision (e.g., are the criteria sufficiently conservative to fit corporate policy for this level of risk assessment?)

Transparency

It must be clear, at least qualitatively:

- How rigid the criteria are (e.g., are they standards in the context of risk from land contamination; are they absolute indicators of unacceptable risk even if not standards; or are they flexible screening values?)
- What level of unacceptable harm or pollution underlies the criteria.
- Whether background exposure or relative risk has been considered and how.
- What assumptions underlie the criteria.
- What uncertainty is included within the generic assessment criteria.
- What factors of safety have been included.

Generic Quantitative Risk Assessment:
Deciding the scope of investigation to support generic quantitative risk assessment

Figure 2B
CRITERIA 2

C

Explanatory Note

The assessor needs to consider practical and other constraints and the costs and benefits for collecting particular information to support generic quantitative risk assessment. Some techniques may be more suitable or effective than others in terms of scope of information collected or data quality. These factors will establish what level and type of investigation, should be carried out.

Even at this level of risk assessment, some of the ideal data for a site will require complex investigative techniques or a long time frame for collection. Some data collection methods may simply not be possible given the physical or other characteristics of the site, or may risk making a potential problem worse.

In a number of cases it will be impossible to make any decisions without the collection of further information. In many cases the expenditure and effort will be justified in terms of a better characterisation of the risk, certainty in decision making and ultimately lower overall cost of dealing with the site.

However, in some cases, the cost of investigation may outweigh the cost of remediation. In others, the information gained might not significantly affect the cost of remediation *(e.g., a further £5,000 spent on investigation may still result in the same £30,000 worth of remediation)*. Or the money would be better spent at the remediation stage, for example on analysis to ensure that the remediation is targeted at the relevant areas. In particularly complex cases, the cost of investigation may outweigh the benefits of the proposed use of the site. In all of these cases, the objectives for risk assessment may need to be revisited.

The site-specific circumstances, and the context of the risk assessment, will determine the precise criteria for evaluation of the practicability, cost effectiveness and benefits of investigation on any particular site or for any particular pollutant linkage. However, the examples below show the likely general factors that may influence the decision.

Factors to consider

Practicability

- Access to site;
- Timeframe and phasing requirements;
- Regulatory, health and safety and other management requirements.

Cost

- Total cost of information collection;
- Cost of delay while information is collected.

Effectiveness and benefits

- Sensitivity of risk assessment to the information;
- Extent to which information will match requirements for certainty in decision making;
- Comparison between alternative techniques;
- Comparison with surrogate sources of information;
- Degree to which information could be reproduced at a later date;
- Implications of wrong decision in absence of information, for example failure to establish particular areas of contamination;
- Potential implications of unforeseen remediation costs because of poor quality of information;
- Potential reductions in remediation costs made possible through extra information;

Generic Quantitative Risk Assessment:
Quality issues to be considered when assessing site investigation information

Figure 2B
CRITERIA 3

C

Background

At this point in a generic quantitative risk assessment, the assessor will be comparing available information about the relevant pollutant linkages against the appropriate generic assessment criteria. The quality of the information must therefore be fit for this purpose, which requires an assessment of its quality.

The general parameters that are relevant to assessing quality of information identified in these Model Procedures are:

- Relevance;
- Sufficiency;
- Reliability;
- Transparency.

The specific quality criteria will depend on the context for the risk assessment and the specific parameters being evaluated (see Part 3 – INFO SC1 – SC3). Some typical criteria for each of the general parameters are presented below.

Relevance

- The information should match the required parameters for use of the generic assessment criteria, in particular any specified contaminant type, characteristics of pathways or receptors, or other parameter such as soil type.

Sufficiency

- An appropriate number of samples have been taken to enable comparison with the generic assessment criteria.
- The location and spacing of sample points are sufficient to define zones or identify anomalous features.

Reliability

- Data were obtained in accordance with appropriate quality standards (e.g., for methods of investigation, sample collection, transporting, storing and analysing samples).

Transparency

- The data are unambiguous;
- Uncertainty is highlighted and preferably quantified;
- The provenance of data is clear.

Relevant pollutant linkages and basis for quantitative risk assessment

Figure 2B
OUTPUT 1

O

Explanatory Note

At this stage a preliminary risk assessment should already have indicated the possible pollutant linkages for consideration during the quantitative risk assessment. The purpose of this stage of the process is to confirm the linkages to be considered in relation to the continuing context of the risk assessment. *For example it may be necessary to drop some of those from the preliminary risk assessment in the light of changed circumstances of the site, or add some as a result of wider considerations.*

The simple example below is that used throughout the risk assessment and options appraisal section of the Model Procedures. In this example, the conceptual model established at the preliminary risk assessment stage is now being considered for quantitative risk assessment. The pollutant linkages identified within the conceptual model are therefore considered **relevant pollutant linkages** for the purpose of quantitative risk assessment.

Context of quantitative risk assessment

The assessor should review the context of the risk assessment, for example considering or updating the parameters identified in Figure 2A INPUT 1 – in this case all of the pollutant linkages identified from the preliminary risk assessment are taken forward (as relevant pollutant linkages) to the next tier of risk assessment.

Description of site

The site (≈ 0.5 hectares) was formerly occupied by an engineering workshop. It is currently being considered for redevelopment for residential purposes – all of the proposed dwellings will have private gardens. The site is located in an urban area with established residential properties on all boundaries.

The site is generally level. The site geology is made ground overlying sands and gravels overlying marl. A river is located approximately 150 m to the east of the site.

Relevant pollutant linkages for quantitative risk assessment

Contaminant	***Pathway(s)***	***Receptor***
Metals A, B, C	• *Ingestion, inhalation, direct contact*	• *Future residents, site workers, (possibly) neighbours*
	• *Consumption of contaminated vegetables*	• *Future residents*
Semi-volatile, non-halogenated hydrocarbons D, E, F	• *Dermal contact* • *Migration through made ground* • *Migration through gravels*	• *Future residents* • *Groundwater in gravel* • *River*
Volatile halogenated hydrocarbons X, Y, Z	• *Migration into buildings* • *Migration through made ground* • *Migration through gravels*	• *Future residents* • *Groundwater in gravel* • *River*

Site investigation report

Figure 2B
OUTPUT 2

O

Site referencing information

Name of site	Site ownership
Address(es)	Site occupation
Location (including NGR)	Plan and size of site

Context of site investigation

Commissioning organisation	Characteristics of site and preliminary conceptual model
Terms of reference	Rationale for investigation and specific objectives

Methods of site investigation

Scope, overall strategy, programme	Health and safety controls
Quality assurance plan	Environmental controls

Sampling and field work

Sampling design	Ground investigation techniques, including sample management
Visual Inspection and on-site testing methods	Monitoring programme and/or supplementary investigation

Laboratory analysis

Sample identification (ID) and testing schedules	Methods and reference standards
Laboratory identification (ID)	Quality assurance and control
Retention of samples	

Results

On-site observations	Laboratory analyses
General ground conditions	Monitoring data
Geological and hydrogeological regime	Confidence limits and other limitations of the data
Field description of samples (by media type)	Evaluation of data against original objectives (e.g., with reference to conceptual model, zoning or other features of site)

Supporting information

Maps, plans (including cross-sectional presentation of data as appropriate)	Borehole/trial pit logs, etc. (including well construction)
Photographic records	Certificates of Analysis
	Chain-of-custody records

Generic Quantitative Risk Assessment:
Risk assessment report

Figure 2B
OUTPUT 3

O

Site referencing information

Name of site

Address(es)

Location (including NGR)

Site ownership

Site occupation

Plan and size of site

Decision records

Summary of context and objectives of risk assessment

Summary of site characteristics and setting; reason for and objectives of risk assessment

Use of generic assessment criteria (GAC)

GAC used and why they are appropriate

The basis (including assumptions) and parameters used to develop GAC

Pollutant linkages evaluated using GAC

Description of pollutant linkages and criteria, and assumptions used for each linkage

Unacceptable risks identified from these linkages

Clear statement of actual or potential unacceptable risks identified, explicitly, including any uncertainty

Identification of pollutant linkages not to be considered further, with reasons

Further action

Details of action, *for example further assessment using detailed quantitative risk assessment, options appraisal for remediation*

Explanation of generic quantitative risk assessment

Context and objectives of risk assessment

Characteristics of site and conceptual model

Assessment of use or development of generic assessment criteria

Information obtained during risk assessment (with reference to relevant site-investigation reports)

Refinement of conceptual model

Evaluation of risks

Selection of generic assessment criteria

Derivation of generic assessment criteria

Assessment of data quality

Method and results of comparison with GAC

Uncertainty and information gaps

Description and justification of next steps

Flowchart for Detailed Quantitative Risk Assessment

KEY PROCEDURAL POINTS

KP1

The decision to carry out a detailed quantitative risk assessment may be made at a number of earlier points in the overall process

KP2

This may require updating the output from the preliminary risk assessment stage

KP3

This applies for each pollutant linkage

KP4

Depending on the risk assessment context, options might include:

- *Keep the assessment under review*
- *Collecting further information*
- *Moving to the risk management stage*

KP5

This depends on the context of the risk assessment & site circumstances For example, it may be necessary to obtain more information to quantify risks in more detail or establish the mechanisms by which risks are created

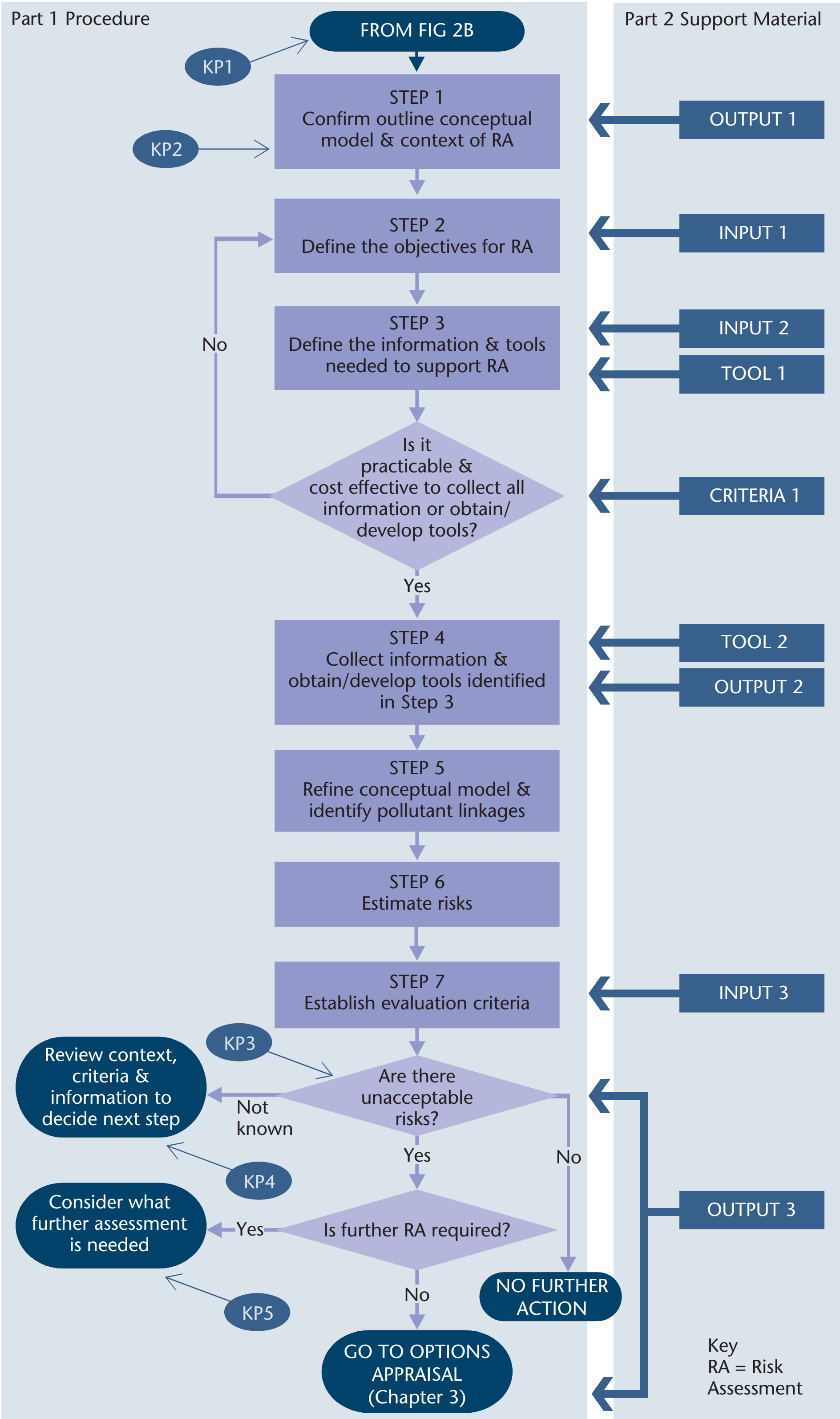

Figure 2C | Detailed Quantitative Risk Assessment

II

Detailed Quantitative Risk Assessment (Section 2.4 of Part 1)

Contents

INPUTS	INPUT 1	Factors to be taken into account when defining objectives for detailed quantitative risk assessment
	INPUT 2	Requirements for information and tools to support detailed quantitative risk assessment
	INPUT 3	Specific evaluation criteria
TOOLS	TOOL 1	Tools for detailed quantitative risk assessment
	TOOL 2	Methods for collecting information to support detailed quantitative risk assessment
CRITERIA	CRITERIA 1	Factors that influence the scope of investigation to support risk assessment
OUTPUTS	OUTPUT 1	Relevant pollutant linkages
	OUTPUT 2	Site investigation report to support detailed quantitative risk assessment
	OUTPUT 3	Risk assessment report

Detailed Quantitative Risk Assessment:
Factors to be taken into account when defining objectives for detailed quantitative risk assessment

Figure 2C
INPUT 1

I

Explanatory Note

As in generic quantitative risk assessment, the factors to be taken into account build on the context and objectives for the risk assessment from the preliminary risk assessment stage. Where appropriate, they will also include information and findings from generic quantitative risk assessment.

Factors will therefore include those listed in Figure 2B INPUT 1. However, there may be additional emphasis on some of these, or new factors that relate to the complexity and issues raised by detailed quantitative risk assessment. *For example, there may be more emphasis on obtaining independent data or review of the approach, or there may be a need for greater focus on the behaviour of particular contaminants.*

This stage of risk assessment involves more detailed collection and assessment of information, and it is essential at the outset to refine the objectives for detailed quantitative risk assessment to focus this information collection efficiently. This may require review of the context of the risk assessment, for example considering or updating the parameters identified in Figure 2A INPUT 1 or in Figure 2B INPUT 1.

The factors and examples below indicate the sort of issues that may need to be considered in formulating the objectives and constraints.

Factors	Already considered for generic quantitative risk assessment or *additional to this tier of detail	Particular features of detailed quantitative risk assessment
Technical	Complexity of site and ground conditions	Complex sites are more likely to be considered and assessment requires a thorough understanding of underlying science, ground properties and dynamic processes. More detailed consideration of particular zones may be required.
	Nature of pollutant linkages	Could require highly specialist information and an assessment of the complexity of linkages, including toxicity effects and the attributes of individual contaminants, pathways and receptors.
	Synergistic or cumulative factors	More likely to be considered and require specialist toxicological and environmental fate and transport knowledge.
	Timeframe for risk assessment	This could be more complex, as the refinement of risk assessment to specific criteria may introduce more detailed timeframes for assessment.
	Potential changes in site circumstances	The time and cost of detailed quantitative risk assessment mean that early input on any likely change to site circumstances is particularly important to avoid abortive or incomplete efforts.

(Cont.)

Detailed Quantitative Risk Assessment:
Factors to be taken into account when defining objectives for detailed quantitative risk assessment (Cont.)

Figure 2C
INPUT 1

I

Technical	*Risk estimation models	These are still evolving across all fields of risk assessment. The selection or development of the appropriate one for any particular site needs specialist knowledge.
	Handling data uncertainty	Particularly important for complex data over time.
Management	Management aspirations	A decision to carry out detailed risk assessment means an investment in time and money. The reason for the risk assessment must be clear at the outset to assist in judging the appropriate input to the process.
	Regulatory requirements	Detailed quantitative risk assessment may be required to support a key regulatory decision.
	Need for consultation and agreement with stakeholders	Detailed risk assessment may involve issues that are complex in both scientific and policy terms. Discussion with different interest groups may be more necessary and more complex as a result.
	Constraints on time and/or budget	Detailed risk assessment may raise more questions than it answers. Staging of information collection, and clear checkpoints in terms of deadlines and budgets could be critical to ensure that all parties are clear about what results might be obtained.
	Risk communication	Explaining, justifying and defending the approach used is likely to be more demanding – transparency is essential.
Social	Factors of safety required	Particularly important in areas of relatively new science.
	Degree of confidence required	Needs to be explicit and realistic.
	Independence of data and evaluation	More likely to be critical to achieve the required level of confidence.
	Public perception	The particular characteristics of an actual or seemingly more complex site, or move away from the use of generic assessment criteria to site-specific assessment criteria may influence acceptance of solutions

Requirements for information and tools to support detailed quantitative risk assessment

Explanatory Note

As in generic quantitative risk assessment, the information requirements for detailed quantitative risk assessment will depend on the:

- Substances under assessment;
- Receptors being considered;
- Complexity of the site, particularly if there are mixtures of contaminants.

However, the range of information may be broader.

The particular approach to risk assessment needs to be established first to enable the identification of information requirements

(see Figure 2C TOOLS 1 and TOOLS 2 and Part 3 – Key information sources: Risk assessment).

The following provides a general list of types of information about the site and its surroundings that are likely to be needed for detailed quantitative risk assessment.

Information for detailed quantitative risk assessment – general (and see Figure 2B INPUT 3)

- Information about the contaminant;
- Information about the ground matrix;
- Information about the receptors;
- Information about the pathways;
- Other site conditions.

Information for particular type of risk assessment

Examples for ecological receptors:

- Direct toxicity test data geared to specific key or indicator organisms and soil functions;
- Tissue residue data;
- Results of full-scale field ecological surveys;
- Spatial exposure modelling data;
- Data on status and condition of ecosystems in similar but uncontaminated locations for comparative purposes and to support the "multiple lines of evidence" approach.

Explanatory Note

As part of the assessment of risks, the assessor has to determine what evaluation criteria to use in judging risks. These criteria are likely to be related more directly to the effect that the contaminant has on the receptor than is the case for criteria that are used in the context of generic quantitative risk assessment (in the case of generic quantitative risk assessment, the criteria will have been chosen as surrogates or indicators). *For example, a typical specific criterion for human health risk assessment could be a limit on the intake of a contaminant by a child, whereas an equivalent generic criterion would be the concentration of that contaminant in the soil.*

It will also be necessary to define criteria for deciding whether the probability of particular harm or damage occurring would itself be considered unacceptable. *For example, a relatively low probability of harm to a child might be considered unacceptable; the same probability of harm to an adult might not.*

The exact choice of evaluation criteria will depend on:

- The context of the risk assessment;
- The conceptual model and the particular pollutant linkage(s) involved;
- What evaluation criteria have been set by authoritative bodies;
- The practicability of measuring or predicting against potential criteria;
- The state of knowledge (e.g., on the mechanism whereby contaminants affect receptors);
- The degree of precaution required;
- The need for confidence and acceptance by stakeholders.

The assessment will also have to take into account the level of confidence required to judge whether a risk is unacceptable. For example, in a legal context the burden of proof in criminal cases is *'beyond reasonable doubt'*; in other cases it may be '*on the balance of probabilities*'.

Examples of criteria that might be used in relation to human and ecosystem receptors **only** are set out below.

Human health

Tolerable Daily Intake (TDI)	**See Part 3: INFO-RA2-2** in particular:
Mean Daily Intake (MDI)	DEFRA/Environment Agency, *Contaminants in Soils: Collation of Toxicological Data and Intake Values for Humans. Consolidated Main Report*, CLR 9, 2002
Index Dose	DEFRA/Environment Agency, *Contaminants in Soils: Collation of Toxicological Data and Intake Values for Humans*, TOX series, 2002
	Note that CLR 9 contains advice on recognised and authoritative UK and international sources of information on the health effects associated with contaminants that can assist in the identification of appropriate health-based criteria.

(Cont.)

Ecosystems

Criteria are likely to be defined on a site-specific basis, taking into account the ecological value of the site or other areas that may be affected. The criteria adopted will depend on the ecological assessment endpoints and associated measurement endpoints identified for the site.

Ecological assessment endpoints describe the characteristics that are to be protected. They may relate to any of the four main levels of ecological organisation. *Examples of types of criteria in this framework are:*

- Ecosystem level – specified changes in ecosystem productivity, nutrient cycling and regeneration or energy flows;
- Community level – specified changes in species diversity or the structure of a particular food web;
- Population level – specific changes in population abundance, reproductive success or age, gender and size and structure of a population;
- Organism level – specified changes in reproductive capability, growth or biomass, development or behaviour.

Part IIA defines ecological assessment endpoints for assessing "significant harm" to ecological system effects at designated protected locations in terms of "irreversible adverse change, or … some other substantial adverse change, in the functioning of the ecological system" and "(endangering) the long-term maintenance of the population of (any species of special interest)".

Measurement endpoints are quantitative measures of the ecological response to exposure to contaminants, and relate to specified ecological assessment endpoints. Examples of measurement endpoints are:

- Presence and/or absence of indicator species;
- Biomass, plant cover or yield;
- Number of viable offspring per adult female.

Detailed Quantitative Risk Assessment:
Tools for detailed quantitative risk assessment

Figure 2C
TOOL 1

T

Explanatory Note

A range of tools is available for detailed quantitative risk assessment. These have been produced for different specific substances, types of site and receptors, as well as for complex individual sites or general application in complex circumstances.

Full details of relevant sources and a brief description of each are provided in Part 3 of the Model Procedures.

Some of these tools can be used to derive highly site-specific assessment criteria. The general approach is to use a computer model or other method of risk estimation to derive an assessment criterion measured in a particular medium and point in the pathway (*for example, the concentration of the substance in soil*) so that the estimated risk from the site would not represent an unacceptable risk compared with relevant evaluation criteria. This may involve an iterative process in modelling, or a reversal of the calculation to estimate risk. It also requires careful checking of the sensitivity of the model to particular assumptions, and evaluation of the factors of safety to ensure that the site- specific assessment criteria are sufficiently precautionary in scientific terms.

See

INFO – RA2-1 Key information sources: Risk assessment – general

INFO – RA2-2 Key information sources: Risk assessment – human health

INFO – RA2-3 Key information sources: Risk assessment – water environment

INFO – RA2-4 Key information sources: Risk assessment – gases and vapours

INFO – RA2-5 Key information sources: Risk assessment – ecological systems

INFO – RA2-6 Key information sources: Risk assessment – buildings and services

Detailed Quantitative Risk Assessment:
Methods for collecting information to support detailed quantitative risk assessment

Figure 2C
TOOL 2

T

Explanatory Note

As in generic quantitative risk assessment, the basic method for collecting information for detailed risk assessment is to carry out intrusive investigations on the site and its surroundings. However, a detailed quantitative assessment may need much more extensive information, including, for example, more elaborate field work to develop predictive models or to measure observed effects of contaminants, or additional laboratory work or other research to establish or derive parameters for modelling.

The information collected should provide sufficient information to support the use of the detailed quantitative risk assessment approach. However, some of the information may be similar to that needed for generic risk assessment, and the assessor should consider what information is already available, or, if appropriate, whether the information needs can be combined for efficient site investigation.

Much of the more specific work for this type of risk assessment may require specialist methods and tools. However, a range of guidance is available that describes how to carry out general aspects of this type of investigation – full details of relevant sources and a brief description of each are provided in Part 3 of the Model Procedures.

The information collected must meet the relevant quality criteria for the detailed quantitative risk assessment. The general parameters that are relevant to assessing quality of information identified in these Model Procedures (see, for example, Figure 2B CRITERIA 3) are:

- Relevance;
- Sufficiency;
- Reliability;
- Transparency.

The specific quality criteria will depend on the context for the risk assessment and the specific parameters being evaluated (see Part 3 – INFO SC1 – SC3).

INFO – SC1	Key information sources: Site characterisation – general
INFO – SC2	Key information sources: Site characterisation – sampling design
INFO – SC3	Key information sources: Site characterisation – laboratory analysis
INFO – PM1	Key information sources: Project management – guidance specific to a particular industrial or commercial sector
INFO – PM2	Key information sources: Project management – health and safety and quality management

II

Detailed Quantitative Risk Assessment:
Factors influencing scope of investigation to support detailed quantitative risk assessment

Figure 2C
CRITERIA 1

C

Explanatory Note

The same factors will apply as for risk assessment using generic assessment criteria (see Figure 2B CRITERIA 2), but the issue of the cost effectiveness of investigation will be more prominent in the context of detailed quantitative risk assessments, as the costs are likely to be higher.

In some cases, the further detailed assessment will require very specific studies over a considerable time period. The effectiveness and value of these studies needs specialist consideration.

The site-specific circumstances and the context of the risk assessment will determine the criteria for evaluation of the practicability and cost effectiveness of investigation on any particular site or for any particular pollutant linkage. The overall factors are likely to be similar to those identified in Figure 2B CRITERIA 2 and can be developed under the headings shown below:

Factors to consider

- Practicability;
- Costs;
- Effectiveness and benefits.

Detailed Quantitative Risk Assessment:
Relevant pollutant linkages

Figure 2C
OUTPUT 1

O

Explanatory Note

As before, at this stage a preliminary assessment should have indicated the possible pollutant linkages for quantitative risk assessment. Some of the linkages may already have been assessed using generic assessment criteria.

The purpose of this stage of the process is to confirm the linkages being considered in a detailed quantitative risk assessment, and whether any should be combined to consider synergistic or cumulative risks.

The example below is that used throughout the risk assessment and options appraisal section of the Model Procedures. The note to the right of the table indicates the outcome of generic quantitative risk assessment.

Description of site

The site (≈ 0.5 hectares) was formerly occupied by an engineering workshop. It is currently being considered for redevelopment for residential purposes – all of the proposed dwellings will have private gardens. The site is located in an urban area with established residential properties on all boundaries.

The site is generally level. The site geology is made ground overlying sands and gravels overlying marl. A river is located approximately 150 m to the east of the site.

Relevant pollutant linkages for further detailed assessment

Contaminant	***Pathway(s)***	***Receptor***	***Notes***
Metals A and B [1]	• *Ingestion* • *Inhalation* • *Consumption of contaminated vegetables*	• *Future residents*	*Assessed using generic assessment criteria: Possible unacceptable risk from metal A,* **further detailed quantitative risk assessment required to confirm characteristics of exposure pathway** *No indication of unacceptable risk for metal B and* **no further assessment required**
Semi-volatile, non-halogenated hydrocarbons D [1]	• *Dermal contact* • *Migration through made ground to gravel aquifer*	• *Future residents* • *Groundwater* • *River*	*Results unclear from use of generic assessment criteria.* **Detailed quantitative risk assessment needed for each linkage with contaminant D**
Volatile halogenated hydrocarbons X and Z [1]	• *Migration of volatile organic compounds into buildings* • *Migration through made ground to gravel aquifer*	• *Future residents* • *Groundwater* • *River*	*No generic assessment criteria suitable* **Detailed quantitative risk assessment required for each linkage with these contaminants**
Synergies *Substance D* *Substance X*	• *Dermal contact* • *Inhalation resulting from migration into buildings*	• *Future residents*	**Detailed quantitative assessment required**

[1] *Substances C, E, F and Y were not found at concentrations above an appropriate laboratory method detection limit and therefore were not considered to constitute a risk*

Detailed Quantitative Risk Assessment:

Site investigation report to support detailed quantitative risk assessment

Figure 2C
OUTPUT 2

O

Background

The site investigation report for a *detailed quantitative* risk assessment will cover much of the same type of information as the equivalent for a generic quantitative risk assessment (see Figure 2B OUTPUT.2). However, it is likely to contain more detailed information and results from more specialist investigations (*for example, that required to input into the development and use of risk estimation models).*

Basic site investigation information (as in Figure 2B OUTPUT 2):

- Site referencing information;
- Context of site investigation;
- Methods of site investigation;
- Sampling and field work;
- Laboratory analysis;
- Results;
- Supporting information.

Specific site investigation information, e.g.

- Toxicity test data;
- Model validation.

Detailed Quantitative Risk Assessment:
Risk assessment report

Figure 2C
OUTPUT 3

O

Site referencing information

Name of site	Site ownership
Address(es)	Site occupation
Location (including NGR)	Plan and size of site

Decision records

Summary of site context and objectives of risk assessment

- Summary of site characteristics and setting; reason and objectives for risk assessment

Pollutant linkages evaluated using detailed quantitative risk assessment

- Description of pollutant linkages, tools used to predict risk, assumptions and criteria used in evaluation

Unacceptable risks identified from these linkages

- Clear statement of unacceptable risks identified, explicitly including any uncertainty
- Identification of pollutant linkages not to be considered further, with reasons

Further action

- Details of action *(e.g., further development of predictive model, appraisal of options for remediation)*

Explanation of risk assessment

Context and objectives of risk assessment

Characteristics of site, preliminary conceptual model and any risk assessment using generic assessment criteria

Approach to detailed quantitative risk assessments

Information and tools obtained or developed during risk assessment

- Assessment of data (quality, zoning, outliers and other anomalous features)
- Evaluation and choice of tools

Refinement of conceptual model

Risk estimation

- Results from estimation techniques
- Development of any site-specific assessment criteria

Evaluation of risks

- Evaluation criteria used
- Method of evaluation
- Results of evaluation
- Uncertainty and information gaps

Description and justification of next steps

Flowchart for Identification of feasible Remediation Options

KEY PROCEDURAL POINTS

KP1

Key output from risk assessment (see Chapter 2)

KP2

These should be based on the nature of the RPL and the wider technical & management context within which the site is being handled

KP3

For example, this may involve supplementary intrusive investigation of the site to determine the full lateral and vertical extent of the pollutant & other relevant ground properties

KP4

In some cases, the only feasible response to the condition of the site may be to implement a long-term monitoring programme to track changes in the behaviour or movement of pollutants. This decision, and all associated monitoring work, should be fully documented.

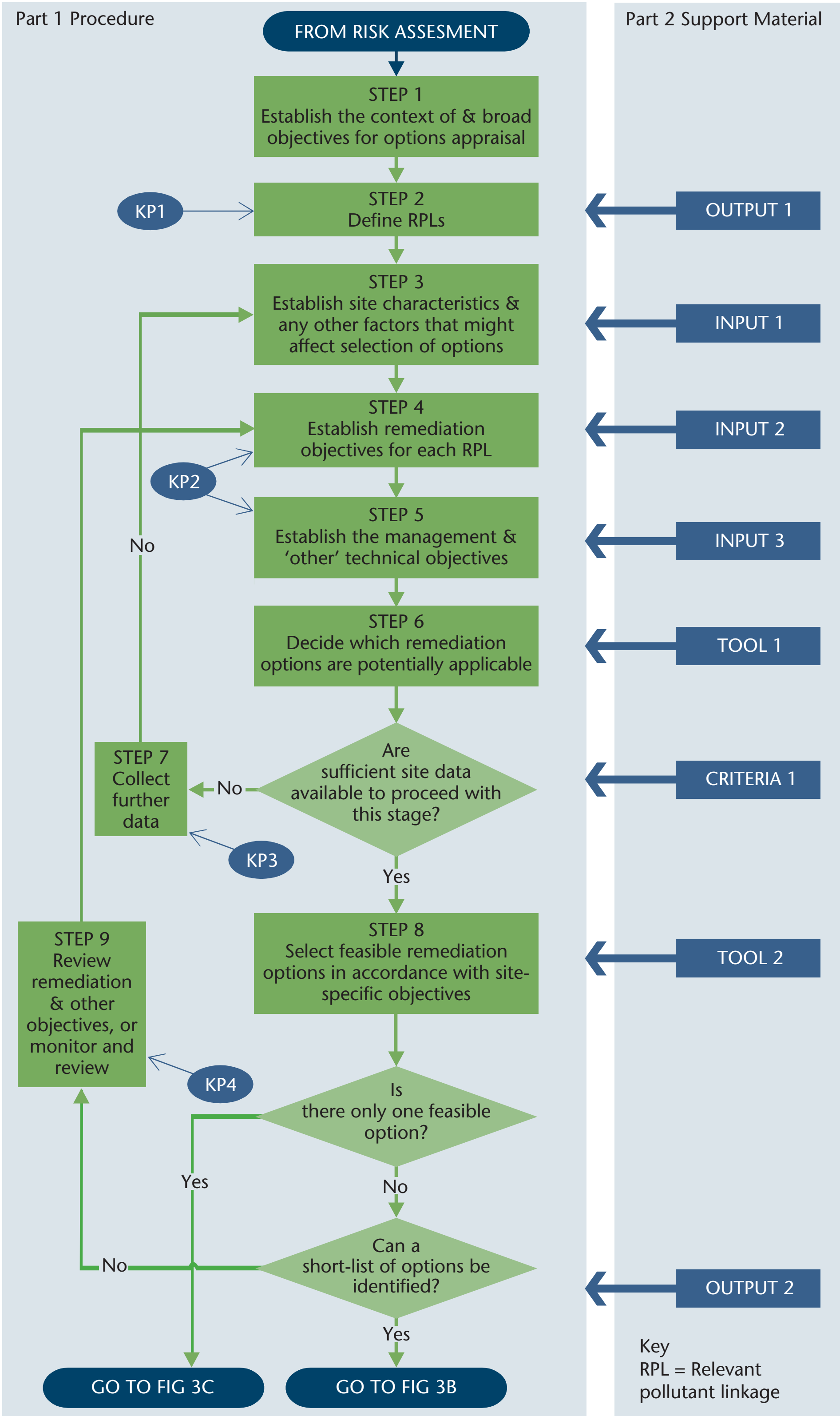

Figure 3A | Identification of feasible Remediation Options

Identification of Feasible Remediation Options (Section 3.2 of Part 1)		
Contents		
INPUTS	INPUT 1	Factors that might affect the selection of feasible remediation options
	INPUT 2	Examples of remediation objectives
	INPUT 3	Examples of management and 'other' technical objectives
TOOLS	TOOL 1	Remediation option applicability matrix
	TOOL 2	Sources of information on remediation options
CRITERIA	CRITERIA 1	Deciding whether sufficient information is available to select feasible remediation options
OUTPUTS	OUTPUT 1	Example summary information on relevant pollutant linkages at the start of options appraisal
	OUTPUT 2	Reporting the identification of feasible remediation options

II

Identification of Feasible Remediation Options:

Factors that may affect the selection of feasible remediation options

Figure 3A
INPUT 1

I

Explanatory Note

The selection of feasible remediation options depends on a range of factors in addition to the physical characteristics of the site and the nature of pollutant linkages. The use and setting of the site, the context within which it is being handled, stakeholder views and timescale may all have a bearing on what might be considered a 'feasible' remediation option in any particular case. While the factors considered relevant to selection will be site specific, typical factors and examples of the type of circumstances that might apply are given below.

Factor	Example circumstances
Site characteristics	
Site setting	*Densely populated area with sensitive receptors in close proximity or remote location with no nearby special features*
Site size	*Small site with limited capacity for operation and storage of heavy plant and equipment or large site with ample working space*
Use and condition of site	*Derelict site with open ground and few physical constraints on remediation or operational site with hardstanding, buildings, structures, plant and vehicles*
Site access	*Ready access with security under the control of remediation personnel or difficult access with no security or security determined by another party*
Site services	*No or limited indigenous capacity to support remediation or ready access to power, water, telecommunications, etc.*
Context	
Legal, commercial, financial	*Planning and development control (e.g., remediation undertaken as part of a larger construction project)* *Corporate environmental policy (e.g., planned financial provision)* *Part IIA of* EPA 1990 *– voluntary or enforcement led* Pollution Prevention and Control (PPC) *– restoration to baseline condition*

(Cont.)

Identification of Feasible Remediation Options:

Factors that may affect the selection of feasible remediation options (Cont.)

Figure 3A
INPUT 1

I

Stakeholder views	
Site owner, funder, insurer or insolvency practitioner	*Tolerance of residual risk; flexibility in use of land; views on long-term maintenance , and monitoring obligations*
Regulator	*Statutory requirements*
	Promotion of best practice
Neighbouring owners	*Impact on property values*
and occupiers	*Short-term nuisance and disruption implications*
Timescale	
In terms of nature of risk	*Immediate risk of adverse effect or effect only after long-term exposure*
In terms of wider context	*Commercial or funding constraints over time*

II

Examples of remediation objectives

Figure 3A
INPUT 2

I

Explanatory Note

Remediation objectives are often expressed in terms of general aims or aspirations, such as to ensure a remediated site is suitable for use or avoids regulatory intervention. Although general aims may be sufficient to commence stage 1 of options appraisal, by the second and third stages general aims should be refined into specific remediation objectives for each relevant pollutant linkage.

Having defined remediation objectives, users should also consider what measures (remediation criteria) might be used to decide whether remediation objectives have been met. These will provide a basis for the development of the formal verification procedures used during the implementation of remediation action (see Chapter 4).

Remediation criteria may relate to the pollutants themselves (e.g. the permitted concentration of a pollutant in a specific medium such as soil or water on completion of remediation); they may be expressed in terms of a performance standard that must be met by particular components of remediation. These performance standards may apply to more than one pollutant linkage.

Examples of general objectives:

- To meet specific planning requirements on the suitability of a site for a planned new use;
- To meet other regulatory requirements (e.g., the 'standard of remediation' under Part IIA of EPA 1990 or restoration to baseline condition under the PPC regulations);
- To avoid regulatory intervention;
- To discharge regulatory duties or exercise powers (e.g., remediation by an enforcing authority);
- To meet stakeholder expectations (e.g., funding body, insurer or neighbouring property owner);
- To facilitate smooth transfer of ownership of land and property;
- To comply with corporate environmental protection policies.

Examples of remediation objectives and criteria related to the pollutant:

To ensure that treated soil shall not exceed a defined concentration of Total Petroleum Hydrocarbons (TPH)	*Compliance to be assessed on the basis that at least 95% of soil samples collected at a frequency of one sample per 250 m^3 will meet the target concentration of 250 mg/kg TPH*
To ensure that the concentration of benzene in groundwater shall not exceed a defined value	*Compliance with a target concentration of 1 µg/litre benzene in groundwater to be measured on the basis of monthly groundwater quality monitoring data for Monitoring Wells 1, 2 and 3 for 6 months following completion of pumping operations, and at quarterly intervals thereafter for a period of 5 years*

Examples of remediation objectives and criteria related to the remediation option:

To ensure a hydraulic conductivity of in-ground barrier materials of a defined value	*Compliance to be assessed on the basis of testing the slurry materials at pre-defined intervals to demonstrate a hydraulic conductivity of less than 10^{-9} m/s*
To ensure an appropriate thickness of surface cover (composite) in all garden areas	*Compliance to be measured on the basis of one measurement per 500 m^2 of placed cover to demonstrate a composite thickness of 1.2 m in all garden areas*

Identification of Feasible Remediation Options:
Examples of management and 'other' technical objectives

Figure 3A
INPUT 3

I

Explanatory Note

Management objectives should aim to define reasonably precisely the specific desired outcomes of remediation, or ways in which it is to be carried out. 'Other' technical objectives are usually defined by wider technical goals (e.g., to produce a particular form of development) or the need to avoid practical problems, such as disruption to ongoing site activities.

Examples of possible management objectives

- To produce a remediation strategy that can be agreed with all key stakeholders
- To meet all regulatory requirements relevant to the installation or operation of remediation options
- To avoid unacceptable health and safety and environmental impacts during remediation
- To minimise long-term liabilities
- To avoid long-term monitoring or maintenance obligations
- To carry out remediation using in-house contractors or external contractors only on a competitive tendering basis
- To carry out remediation in accordance with good technical practice
- To achieve successful remediation within a particular timescale and budget

Examples of 'other' technical objectives for non-operational sites (e.g., sites progressing through the planning and development control process)

- To clear all above-ground buildings and structures by week 5
- To complete infrastructure (roads, building footprints, site drainage, etc.) by week 40
- To re-grade the site profile in accordance with Site Drawing AB/123/Feb-04 by week 8
- To complete realignment of the river frontage in accordance with Site Drawing CD/246/Feb-04 by week 46
- To improve biodiversity in Zone A of the site in accordance with XYZ report dated January 04

Examples of 'other' technical objectives for operational sites (e.g., sites undergoing remediation under Part IIA or PPC regulations)

- To undertake remediation in four phases in accordance with an agreed plant shutdown programme as set out in report EH/240/September 03
- To create a new personnel and/or vehicle access route via Gate 2 for the duration of remediation
- To provide effluent treatment capacity to support remediation subject to strict compliance with conditions attached to an existing consent to discharge (DC/223/01)

Identification of Feasible Remediation Options:
Remediation options applicability matrix

Figure 3A
TOOL 1

T

Explanatory Note

The following (four page) matrix contains summary information on the potential applicability of a range of remediation options to particular contaminant–media type combinations. Remediation options are grouped according to the relevant scientific or technical basis; media type (i.e., whether contaminants are present in soils, made ground or sediments, or in waters); and contaminant type (i.e., whether organic or inorganic substances are being considered).

Potential applicability is indicated in the main body of the matrix as follows:

- √ means a remediation option is potentially applicable to a specific media–contaminant combination;
- x means an option is not applicable to a specific media–contaminant combination;
- ? means a pre-treatment step may be necessary prior to the method being suitable or case study information is inconclusive regarding applicability.

The matrix gives an indication of the broad capabilities of remediation options. To determine whether a particular option is feasible to apply, and how effective it is likely to be in practice, requires consideration of a wide variety of site-specific factors and a greater understanding of the technical merits and limitations of each option (see Figure 3A TOOL 2).

The matrix is based on information contained in Volumes IV to IX (SP 104 to SP 109) of the CIRIA publication, *Remedial treatment data sheets*, as published by the Environment Agency, other Environment Agency publications on remediation and information sources published by CL:AIRE (Contaminated Land: Applications In Real Environments – see Figure 3A TOOL 2).

The matrix covers methods that are commercially available in the UK at the time of publication – other methods may emerge over time and readers should check the technical literature on a regular basis to obtain the most current information.

Notes to matrix

Applicable Media	S = Soils, made ground and sediments	W = Groundwater and surface water

Substance Groups and Examples: Organic Substances	
Volatile organic compounds (VOCs)	Benzene, ethylbenzene, toluene, xylene
Halogenated hydrocarbons	Tetrachloroethene, trichloroethene, trichloroethane
Non-halogenated hydrocarbons	Oil, fuel hydrocarbons, phenol
Polyaromatic hydrocarbons (PAHs)	Benzo(a)pyrene, indeno(1,2,3 cd) pyrene
Polychlorinated biphenyls (PCBs)	209 congeners including PCB 28, 52, 101, etc.
Dioxins and furans	2,3,7,8 –Tetrachlorodibenzo-p-dioxin
Pesticides and herbicides	Dieldrin, hexachlorocyclohexane

Substance Groups and examples: Inorganic Substances and Explosives	
Heavy metals and metalloids	Arsenic, cadmium, lead, copper, zinc
Non-metals	Sulphate, sulphide, nitrate
Asbestos	Amosite, chrysotile
Cyanide	Free cyanide, combined cyanide
Explosives	Trinitrotoluene, trimethylene trinitromine (RDX), nitroglycerine

REMEDIATION OPTION APPLICABILITY MATRIX: ORGANIC SUBSTANCES								
Remediation option	**Applicable media**	Applicable substances						
		VOCs	Halogenated hydrocarbons	Non-halogenated hydrocarbons	PAHs	PCBs	Dioxins and furans	Pesticides and herbicides
CIVIL ENGINEERING METHODS								
Containment – cover systems	S	√	√	√	√	√	√	√
Containment – hydraulic barriers	W	√	√	√	√	√	√	√
Containment – in-ground barriers	S, W	√	√	√	√	√	√	√
Excavation and disposal	S	√	√	√	√	√	√	√
BIOLOGICAL METHODS								
Natural attenuation	W	√	√	√	√	x	x	√
Biopiles	S	√	x	√	√	x	x	√
Bioventing	S	√	√	√	√	x	x	x
Biosparging	S, W	√	√	√	√	x	x	√
Landfarming	S	√	x	√	√	x	x	√
Slurry phase biotreatment	S	√	√	√	√	x	?	√
Windrow turning	S	√	x	√	√	x	x	√
CHEMICAL METHODS								
Chemical oxidation	S, W	√	√	√	√	x	x	√
Chemical dehalogenation	S	√	√	x	x	√	√	x
Soil flushing	S	√	√	√	√	x	x	x
Solvent extraction	S	√	√	√	√	√	√	√
Surface amendments	S	x	x	x	x	x	x	x

Identification of Feasible Remediation Options:
Remediation options applicability matrix (Cont.)

Figure 3A
TOOL 1

T

REMEDIATION OPTION APPLICABILITY MATRIX: ORGANIC SUBSTANCES (CONT.)								
Remediation option	**Applicable media**	Applicable substances						
		VOCs	Halogenated hydrocarbons	Non-halogenated hydrocarbons	PAHs	PCBs	Dioxins and furans	Pesticides and herbicides
PHYSICAL METHODS								
Dual phase SVE	S, W	√	√	√	x	x	x	x
Air sparging	W	√	√	√	x	x	x	x
Soil vapour extraction (SVE)	S	√	√	√	x	x	x	x
Permeable reactive barriers (PRBs)	W	√	√	√	√	√	√	√
Soil washing	S	x	√	√	√	√	x	√
STABILISATION AND SOLIDIFICATION METHODS								
Hydraulic binders (e.g., cement)	S	x	x	?	√	√	√	?
Vitrification	S	√	√	√	√	√	√	√
THERMAL METHODS								
Incineration	S	√	√	√	√	√	√	√
Thermal desorption	S	√	√	√	√	√	x	√

REMEDIATION OPTION APPLICABILITY MATRIX: INORGANIC SUBSTANCES AND EXPLOSIVES

Remediation option	Applicable media	Applicable substances				
		Heavy metals	Non-metals	Asbestos	Cyanides	Explosives
CIVIL ENGINEERING METHODS						
Containment – cover systems	S	√	√	√	√	√
Containment – hydraulic barriers	W	√	√	√	√	√
Containment – in-ground barriers	S, W	√	√	√	√	√
Excavation and disposal	S	√	√	√	√	√
BIOLOGICAL METHODS						
Natural attenuation	W	√	√	x	x	√
Biopiles	S	x	x	x	x	√
Bioventing	S	x	x	x	x	x
Biosparging	S, W	x	x	x	x	x
Landfarming	S	x	x	x	x	√
Slurry phase biotreatment	S	x	x	x	√	√
Windrow turning	S	x	x	x	x	√
CHEMICAL METHODS						
Chemical oxidation	S, W	x	√	x	x	x
Chemical dehalogenation	S	x	x	x	x	x
Soil flushing	S	√	x	x	x	x
Solvent extraction	S	x	x	x	x	√
Surface amendments	S	√	√	x	x	x

REMEDIATION OPTION APPLICABILITY MATRIX: INORGANIC SUBSTANCES AND EXPLOSIVES						
Remediation option	**Applicable media**	Applicable substances				
		Heavy metals	Non-metals	Asbestos	Cyanides	Explosives
PHYSICAL METHODS						
Dual phase SVE	S,W	x	x	x	x	x
Air sparging	W	x	x	x	x	x
SVE	S	x	x	x	x	x
PRBs	W	√	√	x	√	√
Soil washing	S	√	√	x	√	x
STABILISATION AND SOLIDIFICATION METHODS						
Hydraulic binders (e.g., cement)	S	√	√	√	?	x
Vitrification	S	√	√	√	√	√
THERMAL METHODS						
Incineration	S	√	√	√	√	√
Thermal desorption	S	√	x	x	√	x

Identification of Feasible Remediation Options: Sources of information on remediation options

Figure 3A
TOOL 2

T

Explanatory Note

Appraisers may use a variety of information sources to decide whether particular remediation options are 'feasible', and likely to be effective given site-specific circumstances. Possible sources include:

- Recent previous experience in the use of particular methods;
- Information from remediation companies;
- The technical literature.

Recent experience and supplier information are useful initial sources of information; however, it is good practice to review the technical literature on a regular basis to check for independent information on both innovative methods and the practicability and performance of established methods.

Summary information on the technical basis of selected remediation methods can be found in the following: (see Part 3 of Model Procedures, INFO-OA1):

- Environment Agency Remedial Treatment Data Sheets;
- CIRIA, Remedial Treatment of Contaminated Land, Volumes V–IX, (SP 105–109) 1995,

CL:AIRE (Contaminated Land: Applications in Real Environments) is an organisation that actively supports, evaluates and promotes the application of innovative remediation technologies in the UK. In addition to providing fact sheets and technical profiles on particular methods, the CL:AIRE web-site (**www.claire.co.uk**) holds details on research and development projects in the land contamination field.

Information on remediation treatments can also be found on **www.eugris.org** (the European Groundwater and Contamination Land Information System).

Identification of Feasible Remediation Options:
Deciding whether sufficient information is available to select feasible remediation options

Figure 3A
CRITERIA 1

C

Explanatory Note

A substantial amount of reliable information is required about the site and its setting before the feasibility of applying a particular remediation option can be established.

Much of this information may already be available from the data collection activities carried out to support risk assessment. However, further work (which can include supplementary site investigation) may be required to fill information gaps before stage 1 of options appraisal can be attempted.

The available information should allow the appraiser to establish:

- The *identity and general characteristics* of the site to be remediated, including site access, security, services and special features;
- The *environmental setting* of the site, including surrounding land uses and special features in close proximity;
- Prevailing ground conditions;
- The *amount, location and nature of the pollutant(s)* to be addressed (see also Figure 3A – OUTPUT 1);
- The nature of the soil – water matrix that contains the pollutant(s);
- *Likely weather conditions* during the remediation period.

The following checklist illustrates the range and extent of information that may be required.

Site details	• Name and address of site	• Access details and way-leaves
	• Location (including NGR)	• Security arrangements
	• Site plan including boundaries	• Surface condition (open ground and hardstanding)
	• Size of site	• Topography
	• Current ownership and/or occupation of site	• Buildings and other structures
	• Current use and status of site	• Below and above ground services
	• Presence on-site of sensitive ecological or heritage features	• Site geology
Site setting	• Surrounding land uses	• Likely noise restrictions
	• Sensitive ecological, agricultural or heritage features	• Baseline ambient air quality

(Cont.)

Identification of Feasible Remediation Options:

Deciding whether sufficient information is available to select feasible remediation options (Cont.)

Figure 3A
CRITERIA 1

C

Hydrology and hydrogeology	• Surface water features on or close to site • Direction and rate of flow of surface water bodies • Abstraction points or wells on or close to site • Depth to groundwater	• Groundwater vulnerability and aquifer type • Groundwater chemistry • Hydraulic gradient • Thickness of saturated zone • Seasonal variations in groundwater table
Nature of pollutant(s)	• Chemical class • Toxicity • Concentration • Amount and distribution (laterally and vertically) • Physical form (solid, liquid, gas)	• Solubility • Volatility • Density • Biodegradation potential • Partitioning behaviour
Nature of soil/ water matrix	• Solid, liquid, gas • Distribution laterally and vertically • Gas and liquid permeability • Physical properties (e.g., particle size for solids, solids content for waters)	• Chemical composition (e.g., pH, other pollutants, including inhibitors) • Stability (physically and chemically)
Other information	• Likely weather conditions during remediation period	

II

Identification of Feasible Remediation Options:
Example summary information on relevant pollutant linkages at the start of options appraisal

Figure 3A
OUTPUT 1

O

Explanatory Note

Risk assessment should have established which pollutant linkages represent unacceptable risks to health or the environment (see Chapter 2). These pollutant linkages are termed relevant pollutant linkages for the purposes of options appraisal, because some form of remediation action is required to reduce or control risks to acceptable levels. At the start of options appraisal, sufficient information should be available on the relevant pollutant linkages to begin the process of identifying feasible remediation options.

The following example illustrates the type of information about pollutant linkages that will be required. It uses the same conceptual model used in the supporting information to Chapter 2 of Model Procedures (Risk Assessment) and shows that of the nine potential pollutants considered during detailed risk assessment, only three require remediation.

Description of site

The site (≈ 0.5 hectares) was formerly occupied by an engineering workshop. It is currently being considered for redevelopment for residential purposes – all of the proposed dwellings will have private gardens. The site is located in an urban area with established residential properties on all boundaries.

The site is generally level. The site geology is made ground overlying sands and gravels overlying marl. A river is located approximately 150 m to the east of the site.

Pollutant	***Chemical class***	***Pathway(s)***	***Receptor***
A	*Metal*	*Ingestion* *Inhalation* *Consumption of contaminated vegetables*	*Future resident*

Comment
Pollutant A is associated primarily with superficial made ground (vertical extent not exceeding 0.5 m below existing ground level) in the central and eastern parts of the site. Volume of material to be treated ≈ 70 m^3.

Pollutant	***Chemical class***	***Pathway(s)***	***Receptor***
D	*Semi-volatile, non-halogenated hydrocarbon*	*Dermal contact* *Migration through made ground to gravel aquifer*	*Future resident* *Groundwater* *River*

Comment
Pollutant D is present in made ground and natural soils [maximum depth of 3.5m below ground level (bgl)] in the area of the former fuel tank to the north-east of the site and in discrete areas elsewhere. It is present as a free phase liquid (average thickness 0.10 m) on the surface of the groundwater table. Volumes of material to be treated: solids (made ground and natural soils): ≈ 400 m^3; free phase liquid ≈ 50 m^3; dissolved phase liquid ≈ 3000 m^3.

(Cont.)

Identification of Feasible Remediation Options:

Example summary information on relevant pollutant linkages at the start of options appraisal (Cont.)

Figure 3A
OUTPUT 1

O

Pollutant	*Chemical class*	*Pathway(s)*	*Receptor*
Z	*Volatile halogenated hydrocarbon*	*Migration through made ground to gravel aquifer*	*Groundwater* *River*

Comment
Pollutant Z is present at depth (6 m bgl) at the base of the gravel aquifer beneath the former solvent storage tanks located to the west of the site. It is present in both free and dissolved phase forms. Volume of material to be treated: free phase liquid ≈ 50 m^3; dissolved phase liquid ≈ 1000 m^3.

Identification of Feasible Remediation Options:
Reporting the identification of feasible remediation options

Figure 3A
OUTPUT 2

O

Site referencing information

Name of site	Site ownership
Address(es)	Site occupation
Location (including NGR)	Plan and size of site

Context

Summary of site context and objectives

Summary of the legal, financial and commercial context within which the site is being handled and the broad objectives of proposed remediation *(e.g., to achieve a site that is suitable for commercial development).*

Summary description of relevant pollutant linkages

Description of the pollutant linkages that require remediation *(e.g., identity, nature, amount and distribution of pollutants and nature of source material, and characteristics of relevant pathways and receptors).*

Summary of site characteristics and constraints

Description of the site and its setting (including surrounding land uses and presence of any special features) and any other factors that may affect the selection of feasible options *(e.g., limited access and working space, presence of buildings and live services in key parts of the site, short timescale, local community concerns, etc.).*

Decision record

Summary of site-specific objectives

Description of the remediation, management and 'other' technical objectives used to decide whether particular remediation options are feasible.

Shortlist of feasible remediation options

A list and summary description of the feasible remediation options identified for each relevant pollutant linkage.

(Cont.)

Reporting the identification of feasible remediation options (Cont.)

Figure 3A
OUTPUT 2

O

Explanation of the selection of feasible remediation options

Context of and objectives for options appraisal

Methods used to collect information

Site-based information

Literature-based information

Information available

Information on the characteristics of the site and its setting, including any constraints on the selection process

Information on the characteristics of remediation options

Risk assessment information on relevant pollutant linkages, including all necessary supporting options information

Supplementary information on ground conditions collected specifically to aid appraisal

Justification for selection of particular remediation options

Rationale for retention of some options and rejection of others

Caveats and assumptions used during stage 1 of options appraisal

Flowchart for a Detailed Evaluation of Options

KEY PROCEDURAL POINTS

KP1

Refer back to Stage 1 of options appraisal

KP2

These are based on the remediation objectives, management & 'other' technical objectives adopted for the site

KP3

This could range from further desk study, through further site investigation to laboratory or field-scale trials

KP4

The 'technical' and 'financial' parts of the evaluation should be carried out separately as far as possible.

KP5

For example, some criteria may need to be relaxed to allow identification of a practicable option or the evaluation extended to cover other options

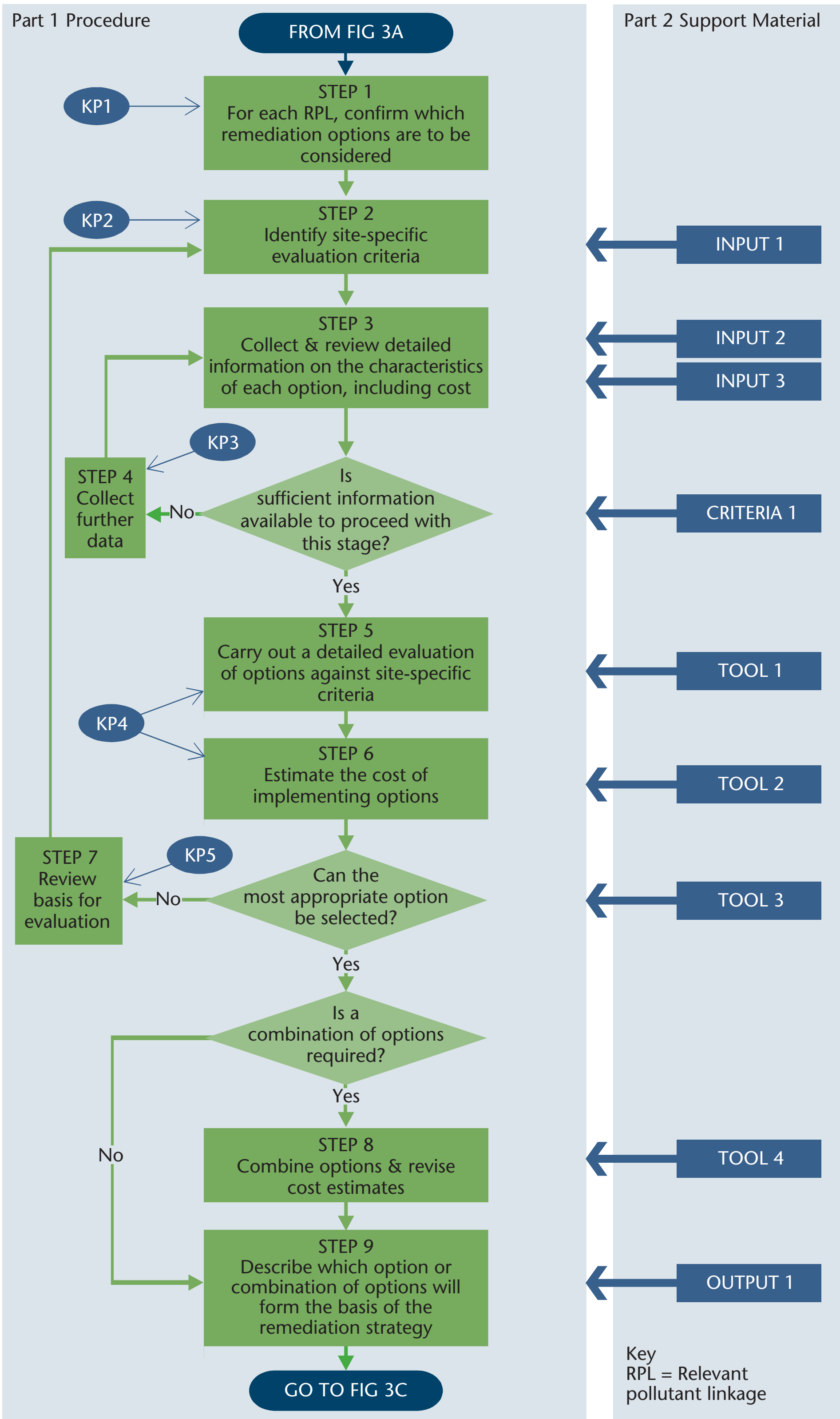

Figure 3B | Detailed Evaluation of Options

A Detailed Evaluation of Options (Section 3.3 of Part 1)

Contents

Detailed Evaluation of Options:
Factors to consider when selecting site specific evaluation criteria

Figure 3B
INPUT 1

I

Explanatory Note

Detailed evaluation criteria are used to test the ability of each feasible remediation option to meet specific remediation, management and 'other' technical objectives. Since objectives are determined on a site- specific basis, it follows that detailed evaluation criteria should also be specific to the site, although many will be common to most sites. Examples of the factors to consider when selecting appropriate criteria are given below.

Note that the statutory guidance to Part IIA of EPA 1990 (Chapter C, DETR Circular 02/2000) sets out very specific criteria for the identification of Best Practicable Technique for the determination of appropriate remediation requirements which may not include all the factors relevant in a wider context.

Typical factors	Example criteria
To satisfy remediation objectives	
Effectiveness	• Extent to which the method will reduce and control the risks associated with the pollutant to an acceptable level within an appropriate timescale and how practicable it will be to verify that objectives have been met
To satisfy management objectives	
Stakeholder views	• Extent to which the method satisfies the requirements of key stakeholders
Operational requirements	• Practicability of installing and operating the method, including site access, storage, support services, etc., and the potential for effective integration with other remediation methods where appropriate
Commercial availability	• Number, identity and geographic location of potential commercial suppliers and expertise
Track record	• Extent of any evidence of successful application of the method in similar circumstances elsewhere
Permissions	• Feasibility of obtaining all relevant permissions and approvals to install and operate the method within the required timescale
Health and safety risks	• Effectiveness in protecting those who carry out remediation or other site personnel and others (including members of the public) who might be affected by remediation

(Cont.)

Detailed Evaluation of Options:
Factors to consider when selecting site specific evaluation criteria (Cont.)

Figure 3B
INPUT 1

I

Typical factors	**Example criteria**
To satisfy management objectives (cont.)	
Environmental impact	• Nature and extent of potential effects on the quality of the environment on or close to the site and in a wider context
Long-term obligations	• Extent to which those who undertake remediation action are able and willing to assume responsibility for any post-remediation maintenance and monitoring, including any long-term obligations
Durability over time	• Extent to which the method is effective in reducing or controlling risks on completion of remediation and for a defined period thereafter
Cost	• Extent to which particular options are reasonable and affordable, given the available resources
To satisfy 'other' technical objectives	
Compatibility	• Extent to which remediation options are compatible with related construction or infrastructure works or other site operations

II

Detailed Evaluation of Options:
Information needed on the characteristics of remediation options

Figure 3B
INPUT 2

I

Explanatory Note

Information on the characteristics of remediation options is available from a variety of sources, including the technical literature (see Part 3: INFO-OA1-OA2) and material produced by technology suppliers. Note that information from independent sources can be extremely useful, especially when the remediation option is highly proprietary in nature.

At the beginning of detailed evaluation, appraisers should have information on the following characteristics for all the remediation options being considered.

Applicability of the method to particular pollutant(s)	Limitations of the method (e.g., related to soil type, presence of inhibiting substances or conditions)
Scientific basis of the method (e.g., engineering-based; physical, chemical or biological process-based)	Track record (e.g., whether established or innovative method)
Mode of operation (e.g., ex-situ or in-situ)	Permissions (for installation and operation of the method)
Time to achieve technical effectiveness	Health and safety risks
Operational requirements (e.g., working space, support services, plant and equipment needs)	Potential environmental impacts
Information needs (e.g., in relation to the nature of pollutant and properties of affected materials)	Durability (e.g., on installation and over time)

Detailed Evaluation of Options:
Typical cost information required for detailed evaluation of remediation options

Figure 3B
INPUT 3

I

Explanatory Note

At this stage of the risk management process, it is sufficient to estimate 'ball park' figures for each of the cost headings listed below. However, it is important to ensure that key costs are not overlooked – for example, long-term monitoring and maintenance may be a significant cost element for some remediation options.

Cost heading	Example
Site preparation	Provision of hardstanding, access roads, site security, accommodation for remediation personnel
Regulatory approvals	Application for licenses and approvals to install and/or operate the method
Project management costs	For management and supervision of remediation
Equipment	Materials handling and processing plant, pumping wells and associated equipment
Mobilisation and start-up	Transport and assembly of plant, equipment and materials, calibration of equipment and other pre-operational checks
Maintenance	Plant modification, repair and long-term performance
Demobilisation	Disassembly of plant and equipment, decontamination measures
Financing	Working capital, interest, depreciation, insurance, taxes, contingency
Labour costs	Salary and expenses
Consumables	Sampling equipment, construction materials, replacement parts
Utilities	Power, water, telecommunications
Health and safety measures	Protective clothing and equipment, project-specific training, independent audit
Environmental protection measures	Containment of dusts, vapours, noise, effluents and similar emissions and associated monitoring procedures (e.g. ambient air quality, discharge of effluents)
Waste disposal	Solid and liquid waste arisings, pollution-control residues
Analytical support	For verification purposes during, on completion and over the long-term if required, to support health and safety and environmental protection needs

Detailed Evaluation of Options:
Example of detailed evaluation of the technical attributes of remediation options

Figure 3B
TOOL 1

T

Explanatory Note

Appraisers may carry out a qualitative assessment of remediation options or they may choose to structure the assessment using some form of quantitative scoring system.

Depending on the context, it may be appropriate to treat all criteria as having equal value. Under Part IIA for example, the Best Practicable Technique is identified on the basis of the most reasonable option(s), that takes account of 'best combination of practicability, effectiveness and durability' [paragraph C19(b), DETR Circular 02/2000], that is not one of these criteria should be considered more important than the other. In other contexts, applying weighting factors to specific technical attributes may be justified. For example, in a redevelopment scheme, a developer may place a high priority on avoiding long-term monitoring obligations; for sites in very sensitive environments, a key priority may be to avoid environmental impacts during remediation.

In all cases, a full account should be given of both the evaluation method used and, where relevant, the reasons for weighting certain attributes.

The table below shows a simple scoring system for evaluating the technical attributes of two alternative remediation options. In the example, particular weight (in terms of total possible score) is given to the technical effectiveness and durability of the two methods.

Evaluation of technical attributes

Aspect	*Total possible score*	*Method X*	*Method Y*
Effectiveness in achieving remediation objectives within appropriate timescale and practicability of verification	40	40	35
Stakeholder requirements	40	40	35
Operational requirements	5	4	5
Commercial availability of technique	5	5	4
Track record of use	5	5	3
Permissions for installation and/or operation	5	4	4
Timescale for implementation	5	5	3
Health and safety impacts	5	3	4
Environmental impacts	5	5	5
Long-term monitoring and maintenance implications	5	5	3
Durability over time	40	40	40
Compatibility with other site works	5	4	5
Score for all technical attributes	**165**	**160**	**141**

Explanatory Note

Appraisers may use a variety of methods to estimate the costs associated with different remediation options, including:

- Recent previous experience;
- Information from remediation contractors;
- The technical literature.

Standard engineering texts (e.g., *Spon's Civil Engineering and Highways Works Price Book* 2003) provide indicative costs for common engineering and materials handling operations, such as excavation, crushing and filling for different material types. Spon's book also contains a section on land remediation costs. The specialist remediation literature may also provide a basis for estimating costs on a site-specific basis.

However, previous experience and information provided by remediation contractors are likely to be the most reliable guide to remediation costs, provided they are based on recent projects that involve sites similar to that being considered. Note that the cost of remediation is strongly affected by the:

- Degree of uncertainty associated with the actual ground conditions;
- Contractor's attitude to pricing risk;
- Commercial climate prevailing at the time the contract is to be let.

Particular care is required to establish what specific costs are covered under general items such as 'preliminaries'.

Further information on remediation costs can be found in Part 3: INFO-OA2.

Detailed Evaluation of Options:
Example of the selection of an appropriate remediation option

Figure 3B
TOOL 3

T

Explanatory Note

Having evaluated the technical attributes of remediation options and estimated the costs involved, the appraiser is in a position to decide which of the feasible options is the most appropriate for any particular pollutant linkage.

Depending on the circumstances, a particular option may emerge as a clear favourite on both technical and cost grounds. In marginal cases, it may be more difficult to choose between different options on the basis of technical merit and costs. In some cases, the appraiser may select an option that scores less highly on technical grounds, but is cheaper to implement, provided key remediation and other objectives can be met and operational and other constraints overcome.

The example below shows this type of outcome for the circumstances introduced in Figure 3B TOOL 1.

Method X is a well-established technique that is used routinely on a commercial basis, and that offers a good long-term solution to the risks posed by the pollutant linkage. Remediation operations could be concluded easily within the required timescale. The estimated cost is £1m.

Method Y is less well-established, although it has a track record of successful use in similar applications and is offered by a reasonable number of specialist contractors. Method Y is also likely to pose fewer short-term health and safety and environmental risks compared to Method X. However, there is more uncertainty about the ability of Method Y to meet remediation objectives within the required timescale and it is likely that some post-completion monitoring will be required. The estimated cost of method Y is £0.5m.

On this occasion, Method Y was selected as the most appropriate option, on the basis that the difference between the two methods on technical grounds was not significant, and Method Y offers potential cost savings some of which can be used to confirm that specified remediation objectives have been met.

Explanatory Note

Depending on the number and nature of pollutants and the complexity of the site, the appraiser may be faced by one of the following typical outcomes:

- There is only one relevant pollutant linkage to be addressed – in this case the most appropriate remediation option for that linkage will form the basis of the remediation strategy;
- There is more than one relevant pollutant linkage, but a single remediation option is able to deal with all the linkages to the required standard – in this case the single remediation option will form the basis of the remediation strategy;
- There is more than one relevant pollutant linkage and more than one appropriate remediation option is required to deal with all the linkages to the required standard – in this case, it will be necessary to combine options maybe as a treatment train to produce a remediation strategy that will deal with the site as a whole. It may also be necessary to consider whether a different overall option can be identified to deal with the site as a whole.

Examples of the ways in which remediation options may be combined

Remediation options may be combined by:

(i) By installing and operating different remediation options in different parts of the site (or at different times) to reflect the nature and location of the material to be treated.

For example, hotspots of hydrocarbons in soil may be excavated and biologically treated using a system of ex-situ biopiles while free phase hydrocarbons in groundwater may be removed using a dual phase extraction system.

(ii) By integrating certain common elements of different remediation options allowing others to proceed along independent routes.

For example, contaminated soils may be treated using excavation followed by on-site segregation and sorting with the resultant segregated soils undergoing different further processing, such as on-site stabilisation, on-site encapsulation and off-site treatment or disposal.

Detailed Evaluation of Options:

Deciding whether sufficient information is available to proceed with detailed evaluation

Figure 3B

CRITERIA 1

C

Explanatory Note

Users should ensure they have sufficient site and method-related information to assess the merits and limitations of each option against detailed evaluation criteria.

Much of the site-based information should already be available from stage 1 of options appraisal, although additional site investigation and/or laboratory or field-scale test data may be required to assess the likely effectiveness of particular options under site-specific conditions.

The type and amount of information required in any individual case will depend on the complexity of the site and the familiarity of the appraiser with different remediation methods. However, the information should be sufficient to be able to decide whether remediation options will:

Satisfy remediation objectives, e.g.

- How effective are the method(s) likely to be given the nature, amount and location of the pollutant(s) involved and nature of the ground conditions in general?
- How long will it take for the method(s) to achieve remediation objectives?
- How will remediation be verified?

Satisfy management objectives, e.g.

- Are the method(s) likely to gain the approval of all key stakeholders?
- Is it possible to accommodate the method(s) on the site given its location, size, access, layout, etc.?
- Where more than one remediation option is likely to be required, is it feasible to combine different methods to deal with the site as a whole?
- Is there evidence for the successful use of the method(s) in similar applications elsewhere?
- How easy will it be to procure the method(s) (e.g., using normal tendering procedures)?
- Is it feasible to obtain all relevant legal permissions and approvals to install and operate the method(s) given the project timescale and resources?
- Is it feasible to provide and implement all the health and safety and environmental protection measures needed to allow safe operation of the method(s)?
- What long-term monitoring and maintenance is likely to be required and who will take responsibility for these?
- What are the operational lifetime(s) of the method(s) likely to be and are these acceptable given the current or proposed use of the site?
- What is the likely cost of implementing the method(s)?

Satisfy 'other' technical objectives, e.g.

- Are the method(s) compatible with any planned construction and/or infrastructure works or other site operations?

Detailed Evaluation of Options:

Reporting the detailed evaluation of remediation options

Figure 3B
OUTPUT 1

O

Site referencing information

Name of site

Address(es)

Location (including NGR)

Site ownership

Site occupation

Plan and size of site

Context

To include information from the identification of feasible options up-dated and revised as necessary

Summary of site context and objectives

Summary description of relevant pollutant linkages

Summary of site characteristics and constraints

Summary of site-specific objectives

Summary of criteria used for detailed evaluation

List and summary description of the criteria used to evaluate each feasible remediation option for each relevant pollutant linkage

Decision Record

Identification of the most appropriate option in each case and which options, if any, need to be combined to produce the remediation strategy.

Explanation of detailed evaluation

Context of and objectives for options appraisal – up-date and revise stage 1 as appropriate in the light of any new information

Methods used to collect information

Information available – to include up-dated and revised stage 1 output where necessary in the light of any new information

Information on the site and its setting, including constraints

Risk assessment information on all relevant pollutant linkages

Shortlist of remediation options brought forward from Stage 1 of options appraisal

Information on the characteristics of remediation options

Supplementary information on ground conditions collected specifically to aid options appraisal, including pilot or field-stage testing

Justification for selection of particular remediation options

What criteria and tools were used and why
Rationale for retention of some options and rejection of others
Rationale for combination of options where appropriate
Full details of options selected, including how they will be verified
Caveats and assumptions used during stage 2 of options appraisal

II

Flowchart for Developing the Remediation Strategy

KEY PROCEDURAL POINTS

KP1

Key output from Stage 2 of options appraisal

KP2

It is likely that the same site-specific objectives will apply as for Stage 2 of the options appraisal – full details should be kept if objectives have to be changed

KP3

This decision should be based on a re-evaluation (including cost–benefit analysis) of the combined strategy

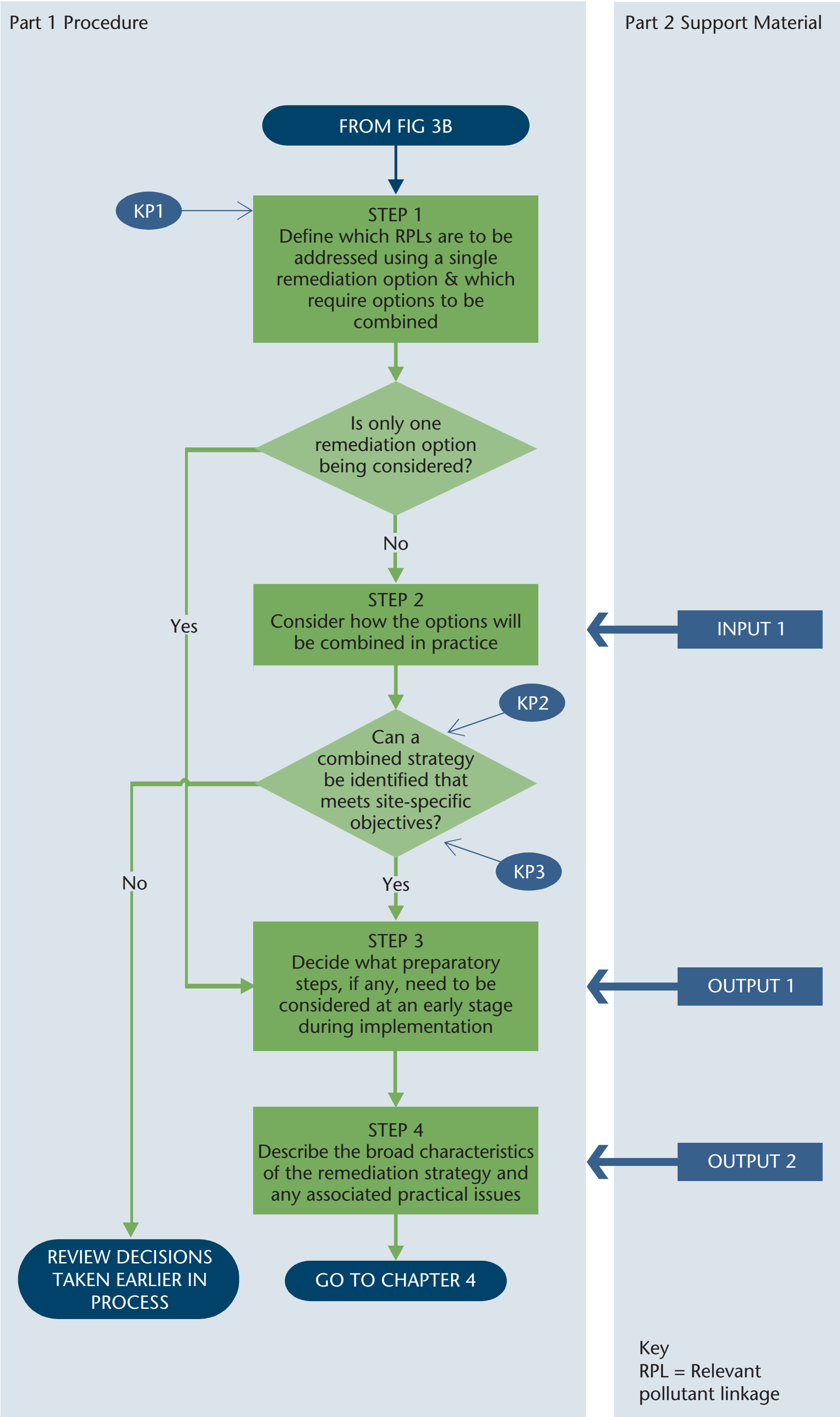

Figure 3C | Developing the Remediation Strategy

Developing the Remediation Strategy (Section 3.4 of Part 1)		
Contents		
INPUTS	INPUT 1	Practical issues arising out of the combination of remediation options
TOOLS	N/A	
CRITERIA	N/A	
OUTPUTS	OUTPUT 1	Preparing for the implementation of remediation action
	OUTPUT 2	Reporting the development of the remediation strategy

II

Developing the Remediation Strategy:
Practical issues arising out of the combination of remediation options

Figure 3C
INPUT 1

I

Explanatory Note

The practicalities of implementing a recommended remediation strategy will be considered in more detail during the planning and detailed design stage of implementation of remediation action (see Chapter 4 of Part 1 of Model Procedures). However, practical and efficiency issues due to combining options are worth considering at this final stage of options appraisal, to check that a combined strategy will work in practice and that any efficiency and cost savings are taken into account.

The examples below give an indication of the type of issues that might be considered in broad terms at this stage of options appraisal.

- Co-ordination
- The number of contractors likely to be involved in the implementation of the remediation strategy
- If more than one contractor, how responsibility for different work packages or phases might be assigned and what lines of communication are likely to be important (note in particular the duties of the *Principal Contracto*r under *CDM regulations* and the possible need for different permits)
- Whether and how the timing or phasing of the work can be adjusted to maximise the capacity of the site to support different activities *(e.g., mobilisation or demobilisation of plant, provision of storage space, provision or capacity of site services)*

Handling contaminated process streams and protecting 'completed' work

- Whether and how combining common elements of different remediation options may affect technical performance or efficiency *(e.g., using common extraction wells and pumping protocols to extract contaminants that have different distributions and physical properties)*
- How working areas might be contained to minimise the potential for recontamination of completed work, especially where remediation is to be phased in space or time

Management of ancillary works to achieve efficiency and cost-savings

- How residues from different work packages or phases might be handled *(e.g., solid and/or liquid waste holding, treatment or disposal capacity)*
- How monitoring for legal compliance purposes might be arranged to deal flexibly with different work packages or phases *(e.g., ambient air quality monitoring, monitoring of discharges to sewer)*
- What verification is required and how it might be handled throughout remediation.

Developing the Remediation Strategy:
Preparing for the implementation of remediation action

Figure 3C
OUTPUT 1

O

Explanatory Note

The planning and design of remediation can be expected to take some time and may be substantial for large sites that involve complex remediation. One advantage of considering the broad practicalities of implementing a remediation strategy during this last stage of option appraisal is that it allows preparatory activities to be identified at an early stage. In some cases, it may be possible to put preparatory activities into place while detailed planning for the main remediation phase is being carried out; in other cases, preparatory activities may be identified as an early priority for planning and detailed design (see Chapter 4 of Part 1 of Model Procedures).

Examples of possible preparatory requirements are given below.

Monitoring

- Baseline monitoring in advance of remediation *(e.g., noise, ambient air or water quality)*

Infrastructure

- Provision of access for plant, vehicles and materials to the site
- Decommissioning, decontamination and demolition of existing buildings or structures
- Construction of temporary infrastructure, such as haulage roads or hardstanding
- Re-routing of underground or above ground services

Developing the Remediation Strategy:
Reporting the development of the remediation strategy

Figure 3C
OUTPUT 2

O

Site referencing information

Name of site	Site ownership
Address(es)	Site occupation
Location (including NGR)	Plan and size of site

Context

To include up-dated and revised stage 2 output in the light of any new information:

Summary of site context and objectives	Summary of site-specific objectives
Summary description of relevant pollutant linkages	Shortlist of feasible remediation options
Summary of site characteristics and constraints	Summary of most appropriate remediation options following detailed evaluation

Decision record

Description of the proposed remediation strategy, including:

- Technical and scientific basis, mode of operation, time to achieve technical effectiveness, operational requirements, limitations, permissions, verification requirements, health and safety risks and precautions, potential environmental impact and precautions, durability and cost.
- Practical implications of implementing the proposed remediation strategy including identification of preparatory activities *(e.g., permits, demolition, provision of temporary infrastructure, procurement options, integrated waste handling).*

Description of how the remediation strategy meets the objectives for individual pollutant linkages and the site as a whole.

Explanation of the development of the remediation strategy

To include up-dated and revised stage 2 output where necessary in the light of new information:

Context of and objectives for options appraisal	Risk assessment outcome and relevant pollutant linkages
Methods used to collect information	Characteristics of remediation options
Information available on the site and its setting, including any constraints	Supplementary information on ground conditions

Justification for development of the remediation strategy

Caveats and assumptions used during the development of the strategy

Outcome of checks that any combined strategy continues to meet site-specific objectives

Flowchart for Preparation of the Implementation Plan

KEY PROCEDURAL POINTS

KP1
Key output from options appraisal stage

KP2
This step may be used to consider if there are any data gaps that would prevent detailed design of the remediation strategy

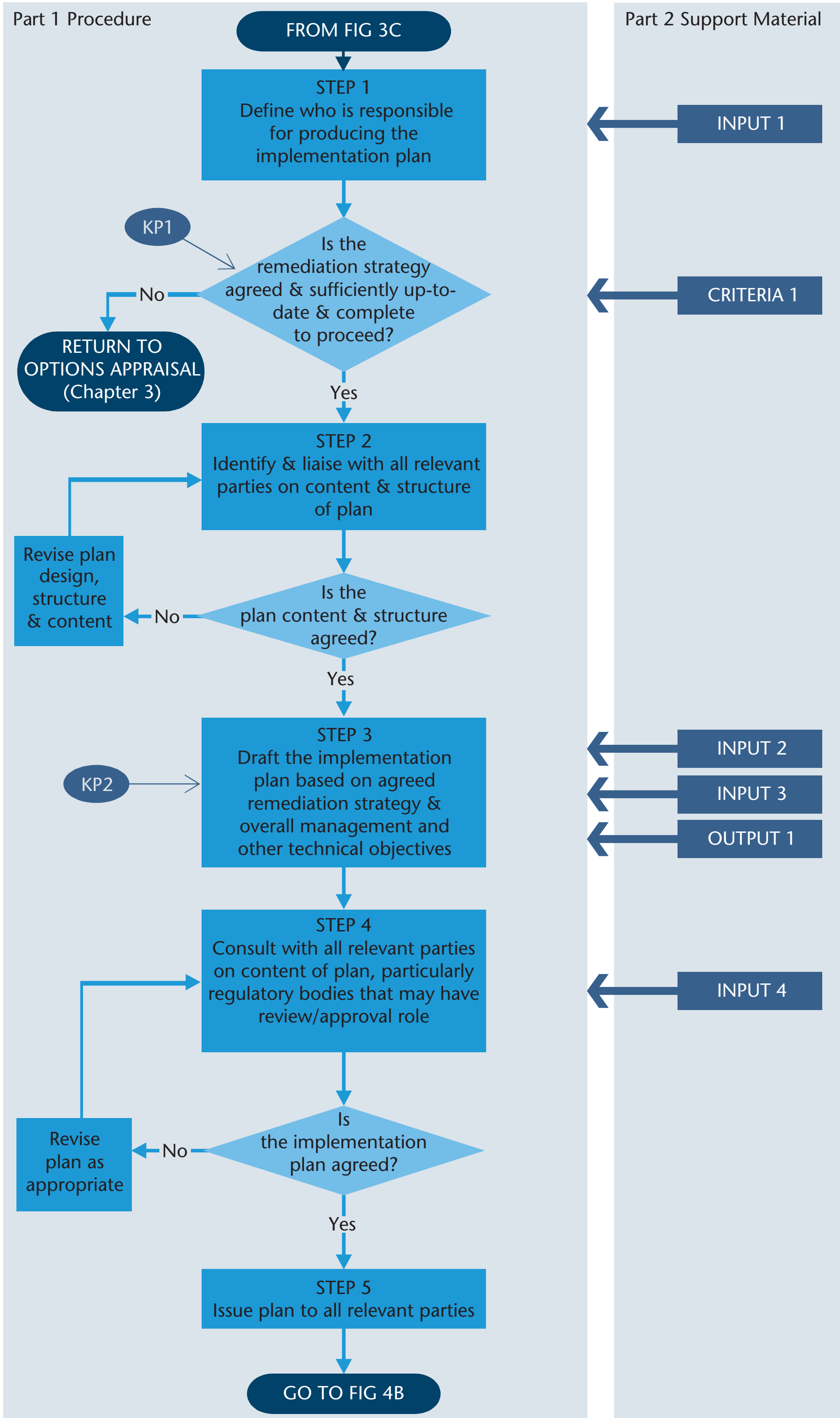

Figure 4A | Preparation of Implementation plan

Preparation of the Implementation Plan (Section 4.2 of Part 1)

Contents

INPUTS	INPUT 1	Deciding who will produce the implementation plan
	INPUT 2	Defining the procurement strategy
	INPUT 3	Filling information gaps during design and implementation
	INPUT 4	Who might be consulted and what consultees might look for in an implementation plan
TOOLS	N/A	
CRITERIA	CRITERIA 1	Criteria to assess whether the remediation strategy is complete and up-to-date
OUTPUTS	OUTPUT 1	Typical content of an implementation plan

Preparation of Implementation Plan: Deciding who will produce the implementation plan

Figure 4A
INPUT 1

I

Explanatory Note

The implementation plan will underpin the way in which remediation is carried out, and needs to be prepared taking into account a broad range of issues. Note that remediation that takes place in isolation from other site developments will affect the choice of organisation that produces the plan.

	Plan may be compiled by	In consultation with
Contract to deal with remediation only	• In-house Project Manager and/or Expert • Environmental Consultant • Specialist Contractor	• Client • Regulatory authorities • Civil Engineering Consultant • Project Management Consultant • Quantity Surveyor • Legal advisers • Contract laboratory • Operator of landfill and/or waste treatment facility
Contract to cover a wider range of activities than just remediation	• In-house Project Manager and/or Expert • Environmental Consultant • Civil Engineering Consultant • Project Management Consultant	• Client • Regulatory authorities • Specialist Contractor • Quantity Surveyor • Legal advisers • Contract laboratory • Operator of landfill and/or waste treatment facility

Preparation of Implementation Plan:
Defining the procurement strategy

Figure 4A
INPUT 2

I

Explanatory Note

A number of approaches to procurement are available and advice should be taken from procurement professionals on the strategy that will best suit the particular circumstances of the project. Options include those listed below.

Traditional	Client directly employs Designer and Contractor using separate contracts Client can require lump sum or remeasurable basis of payment May require longer programme period to include competitive tendering of each role Provides for independent supervision of site activities Creates possible contractual conflict if consultant's design implemented by a Contractor fails to meet expectations
Design and build	Client directly employs Contractor to provide both design and implementation Client may agree transfer of their initial professional advisers to Contractor Usually procured on a lump-sum basis Can be a means to fast-track activities when time is short Can be a means of passing complete responsibility for the work to a third party Contractor may employ specialist sub-contractors to design and undertake specific work packages Creates possible contractual conflict if scope of work changes
Partnering	Client employs Designer and Contractor using partnering approach Openbook cost and remuneration system possible Client and Contractor may agree target cost with a sharing of cost savings and/or over-runs Allows for flexible approach to solving unexpected problems
Management contracting	Client directly employs Designer and Management Contractor using separate contracts Management Contractor appoints individual specialist contractors to deliver separate packages of work, sometimes including design duties Can be a means to fast-track activities when time is short Work packages can be let as lump sums or on a remeasured basis

Preparation of Implementation Plan:
Filling information gaps during design and implementation

Figure 4A
INPUT 3

I

Explanatory Note

The remediation strategy may have been completed as far as practicable, but may still contain information gaps that need to be filled during the design or implementation stage.

Typical information gaps	Possible actions to fill them
Existing physical conditions on the site not fully defined	Undertake further targeted site investigation
Effectiveness and/or operational performance of remediation technologies need clarifying	Undertake treatability studies
Existing chemical conditions on the site not fully defined	Undertake further targeted site investigation, testing and monitoring
Actual extent of area that requires treatment unclear	Undertake further targeted site investigation
Volume of contaminated material not defined	Undertake further targeted site investigation
Likely timescale for technology to achieve remediation targets unclear	Undertake treatability studies and/or predictive modelling
Future use of site and/or buildings unclear	Establish with client specific uses of site, taking due account of local planning constraints

Preparation of Implementation Plan:

Who might be consulted and what consultees might look for in an implementation plan

Figure 4A
INPUT 4

Consultee[1]	Issues of particular relevance
Client	Will the plan deliver remediation efficiently?
	Does the programme fit with other time constraints?
	Are costs controllable?
	Will liability for contamination be minimised or removed?
	Will the site be suitable for its current or proposed future use and setting?
	Does the remediation impose any future land-use restrictions?
Local Authority	Is the remediation strategy agreed?
	Will the remediation conform to any relevant planning condition or Section 106 agreement?
	Will the remediation conform to requirements under Part IIA of the EPA 1990?
	Are possible nuisances arising from the remediation likely to be controlled effectively?
	Are there clear lines of communication?
	Will the site be suitable for the permitted use(s)?
	Is planning permission required and has it been obtained?
Environment Agency, SEPA, EHS for Northern Ireland	Will the remediation conform to requirements under Part IIA of EPA 1990 or other relevant legislation?
	Does the remediation require any form of regulatory permit, and are these being obtained
	Does the remediation require amendment of an existing environmental permit?
	Is the remediation protective of controlled waters?
	Will the site be suitable for the permitted use(s)?
	Will the remediation affect flood defences?
Legal adviser	Does the plan afford a means to control liability?
	Are the procurement routes and conditions of contract suitable?
	Are suitable warranties available from all relevant parties?
Project manager	Are the contract costs defined?
	Do the proposed contract conditions allow cost certainty, or effective management of variable elements of cost?

(Cont.)

[1] Other consultees might include, for example: English Nature, English Heritage, Scottish National Heritage, Countryside Council for Wales, Environment and Heritage Service in Northern Ireland, and local wildlife groups.

Preparation of Implementation Plan:

Who might be consulted and what consultees might look for in an implementation plan (Cont.)

Figure 4A
INPUT 4

I

Consultee	Issues of particular relevance
Potential purchaser, insurer or funder of land	Will the remediation deliver certainty about the quality of the land? Can the remediation be relied on in legal terms? Will the remediation eliminate or manage any liability that might pass with the land? Is any long-term monitoring or maintenance required?
Interested third party (e.g., local neighbourhood group)	How will impacts on adjoining land be controlled? Will the remediation be suitable to treat the contamination? How long will it take? Will there be many lorry movements on local roads? Will there be any noise, dust and/or odours from the remediation? What are the working hours and days? Will there be roadworks or closure of roads or footpaths?

Preparation of Implementation Plan:

Criteria to assess whether the remediation strategy is complete and up-to-date

Figure 4A

CRITERIA 1

C

Explanatory Note

The remediation strategy may have been prepared some time before the decision to move forward with the work. Before preparing the implementation plan, the strategy should be reviewed to ensure it is still relevant and will achieve the project objectives in the light of any new data.

Factors that may have changed and should be taken into account in revision of the strategy:

- Changes to surrounding land use;
- Changes to use of land on site;
- Results of the most recent monitoring at the site;
- Regulatory requirements for the standard of remediation;
- Changes to the need for Licences and/or Permits to carry out the work;
- Changes in budgets available for the work;
- Changes in timescales by which the work must be complete;
- Need to incorporate other works into the strategy;
- Commercial availability of particular remediation techniques.

Checklist by which to judge the completeness of the strategy:

- Will the strategy deal with each relevant pollutant linkage?
- Is the strategy protective of all relevant receptors (i.e., human health, groundwater, surface water, ecology, livestock, domestic animals, buildings)?
- Does combining the strategy with other aspects of work on site compromise its ability to render the site suitable for use?
- Is the strategy practical?
- Will the remediation be effective and durable?
- Can the design be completed based on the currently available information?
- Can the remediation be completed in the time available?
- Can the remediation be completed within the available budget?

Preparation of Implementation Plan:
Typical content of an implementation plan

Figure 4A
OUTPUT 1

O

Explanatory Note

The implementation plan should bring together all aspects of the remediation project in a systematic manner. The scope of the plan should reflect the size and complexity of the project. Issues to cover include those listed below.

Management and legal considerations	• Project management arrangements • Programme (including phasing, completion and handovers) • Choice of form of contract • Specifications • Warranties • Procurement methods • Resources available to carry out work • Allocation of roles and responsibilities • Communications • Third party approvals (e.g., planning conditions) • Regulatory context (e.g., Part IIA, voluntary remediation) • Health and Safety requirements • Environmental protection requirements (e.g., emissions, noise, smell, nuisance) • Quality management systems • Record keeping
Technical factors	• Scope of work as defined by the remediation strategy • Remediation and other objectives • Site preparation and operational constraints • Site supervision • Monitoring requirements • Verification requirements • Post-contract maintenance • End-point objective for monitoring • Contingency planning • Competence and training of staff
Financial factors	• Capital costs • Running costs • Professional fees • Post-contract monitoring and maintenance costs • Rate of expenditure • Types and levels of contingency • Grant funding receipts

Flowchart for Design, Implementation and Verification

KEY PROCEDURAL POINTS

KP1
Steps 1to 7 – finalise design in preparation for procuring remediation

KP2
Ensure verification of remediation is an integral part

KP3
Agree contractor method statements

KP4
Ensure appropriate levels of supervision are provided

KP5
Completion may be absolute (all objectives achieved) or interim (short-term objectives achieved but treatment may continue for some time to come) as identified within the verification plan

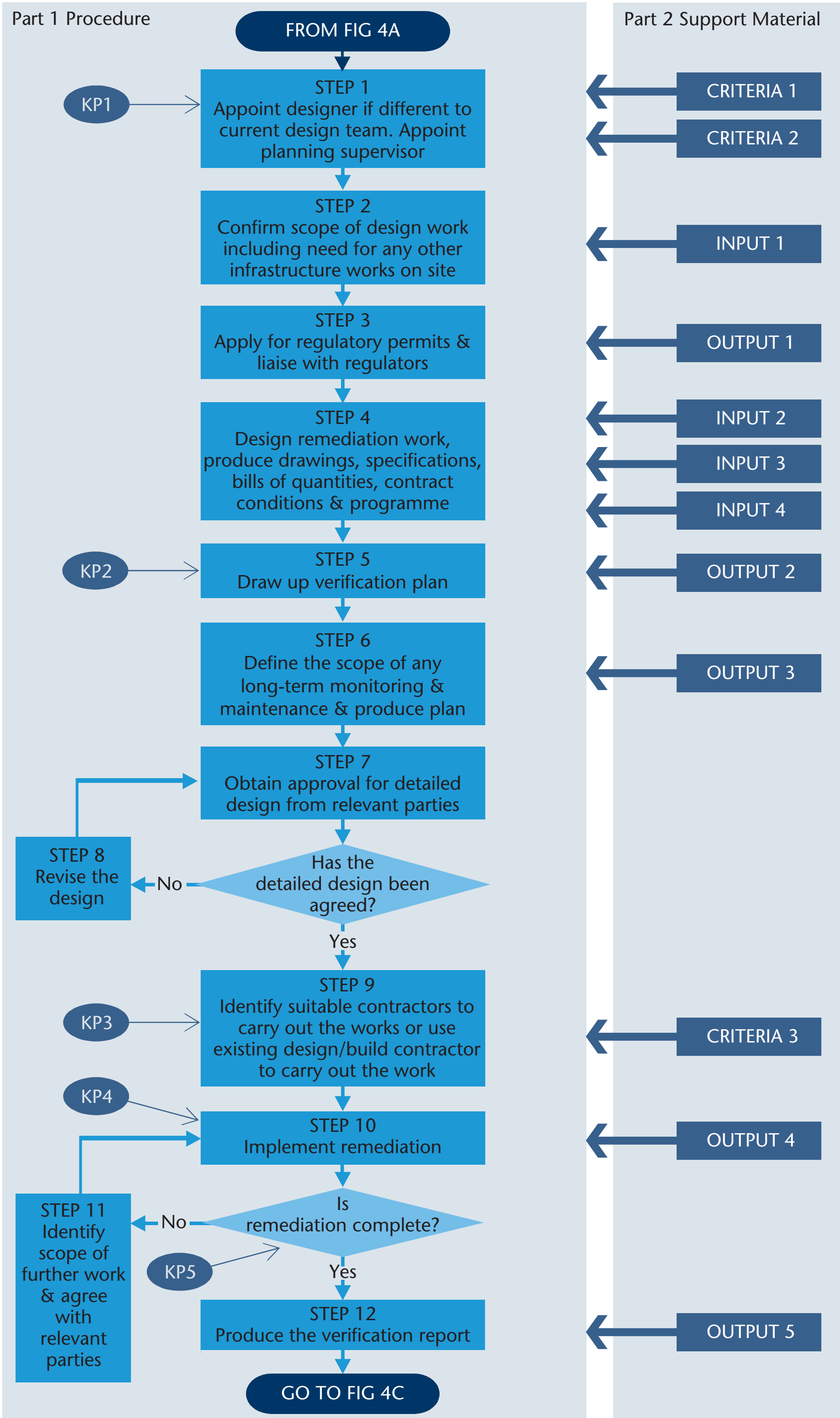

Figure 4B | Design, Implementation & Verification

Design, Implementation and Verification (Section 4.3 of Part 1)

Contents

INPUTS	INPUT 1	Other site works that may link into remediation design
	INPUT 2	Standard forms of contract that may be used for remediation
	INPUT 3	Design considerations
	INPUT 4	Specification options
TOOLS	N/A	
CRITERIA	CRITERIA 1	Factors to be considered when appointing a remediation designer
	CRITERIA 2	Factors to be considered when appointing a planning supervisor
	CRITERIA 3	Factors to be considered when appointing a contractor
OUTPUTS	OUTPUT 1	Typical regulatory permits
	OUTPUT 2	Typical content of a verification plan
	OUTPUT 3	Typical content of a monitoring and maintenance plan
	OUTPUT 4	Typical content of a progress report
	OUTPUT 5	Typical content of a verification report

Design, Implementation and Verification:

Other site works that may link into remediation design

Figure 4B

INPUT 1

I

Explanatory Note

Where the remediation is being carried out on site in isolation from any other activities, it may not be necessary to consider any issues other than those directly associated with remediation. However, where the remediation is in support of, for example, site redevelopment, it will be important to design a combined remediation and infrastructure scheme. Issues that may need to be considered in the combined design include those given below.

- Overall design of development, including proposed basements and other below-ground structures
- Design of building layouts to reduce the impact of any contamination being left on site
- Design of services to minimise long-term risk
- Foundation requirements for new structures, especially where piles, vibro columns or deep foundations are necessary
- Geotechnical requirements, such as slope stability
- Proposed final site levels, and requirements for site regrading to achieve these levels
- The location of soakaways and infiltration-based drainage systems to avoid any areas where contaminated soils are to be retained on site
- Measures to prevent the creation of any new contaminant migration pathways (e.g., piled foundations may create vertical pathways)
- Proposed site-drainage scheme, and requirements for storm and foulwater disposal, especially where drain runs are deep or could form pathways for contaminant migration
- Need to ensure that any treated soil that is re-used on site can be replaced in the ground without need for additional protection measures in the context of the intended site use, otherwise there may be a requirement for a waste management licence
- Need for remediation objectives to be protective of building materials likely to come into contact with the soil

Standard forms of contract that may be used for remediation

Figure 4B
INPUT 2

I

Standard Contract	Applicability
General Conditions of Government Contracts for Building and Civil Engineering Works GC/Works/1 or 2	Used by central government departments
Institution of Civil Engineers (ICE) 6th and 7th Editions	Civil engineering works Re-measured contract
ICE Conditions of Contract for Minor Works	For works of a simple and straightforward nature in which the duration of the contract is less than 6 months and contract value does not exceed £100,000
ICE Conditions of Contract for Ground Investigations.	For site investigation work, although not specifically geared towards contamination investigations
Joint Contracts Tribunal (JCT) Standard Form of Building Contracts	The building equivalent of the ICE Conditions. Not directly applicable to contaminated land projects, but includes variations that provide for other forms of contract rather than admeasurement (e.g., JCT with Contractor's Design)
ICE Model Forms of Conditions of Contract for Lump Sum and Cost–Reimbursement Contracts	For use by the process industries, but may be applicable for some forms of land remediation project
ICE Overseas Conditions of Contract and Fédération Internationales des Ingénieurs – Conseils, (FIDIC) Conditions of Contract	Conventionally used for overseas civil engineering projects (Note FIDIC translates to the International Federation of Consulting Engineers)
Engineering and Construction Contract (ECC) New Engineering Contract	More widely applicable than ICE 6th Edition, covering other forms of contract including cost–reimbursement, design and build, and management contracting options
Project Partnering Contract 2000 (PPC 2000)	The first standard form of contract for project partnering, supported by a related form of contract for Specialist Sub-contracts (SPC) 2000

Design considerations

Figure 4B
INPUT 3

I

Overall scope	The design should: • Be based on the remediation strategy; • Meet remediation objectives (i.e., aim to reduce and/or control both short- and long-term risks); • Meet management and other technical objectives and constraints; • Reflect the need to discharge planning conditions if relevant to the site; • Address output of risk assessment by breaking or eliminating RPLs; • Be compatible with other aspects of site works, such as creating development platforms where required; • Be achievable within programme; • Ensure nuisance, such as dust, odours, noise and dirt on roads, is minimised by design; • Be verifiable by testing, measurement, monitoring or other recording method; • Allow for contingencies to deal with uncertainty; • Be sustainable.
Site information	Site information needed for design purposes includes: • Service locations and working constraints; • Surface water drainage systems (land drains, etc.); • Access limitations; • Permitted working and storage areas; • Location of buried structures, foundations and/or tanks; • Ground conditions, soil strength, permeability, particle size distribution, etc.; • Groundwater conditions; • Surface water proximity and constraints for working; • Neighbouring land uses and constraints; • Site security; • Permit to work systems, working hours; • Surrounding road capacity (will vehicle movements cause negative effects?); • Any seasonal variations in water levels.

(Cont.)

Contamination information	Contamination information needed for design includes: • Types of contamination to be dealt with; • Lateral and vertical extent of contamination; • Mobility of contamination • Presence in soil and/or groundwater; • Presence of dense non-phase liquids (DNAPL) or light non-phase liquids (LNAPL) in groundwater.
Information on remediation technique	Information needed for design purposes includes: • Technical basis of the technique; • Operational characteristics and requirements (e.g., plant and equipment, power, mobilisation details, etc.); • Commercial availability of technique; • Cost of technique; • Availability, capacity and proximity of suitably licensed waste disposal sites (where relevant); • Earthworks issues (i.e., obstructions, hard digging, deep excavations, excavation below groundwater, disposal of pumped water, viability of plant movement in bad weather).
Verification	Verification issues to be considered at the design stage include: • Lines of evidence to inform collection of data sets for key parameters that support agreed remediation criteria to demonstrate the performance of remediation • Frequency, duration, location, determinands, sampling and analytical methods, acceptance criteria, response actions, reporting procedures and regulatory approvals; • Need for ancillary equipment or facilities (e.g., monitoring wells).
Health and Safety	Health and safety is a fundamental part of design. The following issues must be addressed at the design stage: • Construction Design and Management (CDM) Regulations; • Duty of Designer under CDM; • Building safety into design; • Control of substances hazardous to health (COSHH) assessments; • Preliminary Health and Safety Plan.

Design, Implementation and Verification:
Specification options

Figure 4B
INPUT 4

I

Explanatory Note

The specification defines the work required and the quality standards to be achieved. There are two main types of specification.

Method based	• Specifies objectives to be met, and methods to be used to achieve this • Requires good knowledge of site conditions • Requires good understanding of the likely effectiveness of the method • Responsibility for selection of method lies with designer
Performance based	• Specifies objectives to be met and end condition of the site only • Usually used when uncertainty exists around likely performance of specialist technologies • Must ensure that the objectives and required end condition are reasonably achievable • Responsibility for selection of method lies with the contractor

Design, Implementation and Verification:

Factors to be considered when appointing a remediation designer

Figure 4B

CRITERIA 1

C

Company experience	• Able to demonstrate track record of similar projects • Able to demonstrate good project management skills • Employs or has access to multidisciplinary skills • Has a Quality Management System in place • Has breadth of skills to deal with all aspects of the project • Able to demonstrate understanding of interfaces with other aspects of site work • Has appropriate health and safety policies and procedures in place • Has appropriate environmental protection policies and procedures in place
Individual experience	• Project Director and Manager able to demonstrate strong experience and understanding of this type of work • Good technical, management and communication skills • Awareness of wider policy and regulatory issues • Awareness of legal issues that may affect liability for the client • Able to demonstrate Continual Professional Development (CPD) in relevant subjects • Awareness of health and safety duties that fall to the Designer • Awareness of the need for robust verification
Financial probity	• Able to demonstrate sound financial stability of the company • Able to provide evidence of relevant insurances
Contractual issues	• Able to work to major forms of Contract Conditions • Able to provide reasonably worded warranties

Design, Implementation and Verification:

Factors to be considered when appointing a planning supervisor

Figure 4B
CRITERIA 2

C

Company experience	• Able to demonstrate track record of similar projects • Able to demonstrate good project management skills • Has a Quality Management System in place • Able to demonstrate understanding of interfaces with other aspects of site work • Has appropriate health and safety policies and procedures in place • Has appropriate environmental protection policies and procedures in place
Individual experience	• Able to demonstrate strong understanding of this type of work • Good management and communication skills • Awareness of wider policy and regulatory issues • Able to demonstrate CPD in relevant subjects
Financial probity	• Able to demonstrate sound financial stability of company • Able to provide evidence of relevant insurances
Contractual issues	• Able to work to major forms of Contract Conditions

Factors to be considered when appointing a contractor

Figure 4B
CRITERIA 3

C

Company experience	• Able to demonstrate track record of similar projects • Able to demonstrate good project management skills • Employs or has access to multidisciplinary skills • Has a Quality Management System in place • Has breadth of skills to deal with all aspects of the project • Able to demonstrate understanding of interfaces with other aspects of site work • Has appropriate health and safety policies and procedures in place • Has appropriate environmental protection policies and procedures in place
Individual experience	• Project Director and Manager able to demonstrate strong experience and understanding of this type of work • Good technical, management and communication skills • Awareness of wider policy and regulatory issues • Awareness of legal issues that may affect liability for the client • Able to demonstrate CPD in relevant subjects • Awareness of Health and Safety duties that fall to the Principal Contractor • Awareness of the need for robust verification
Financial probity	• Able to demonstrate sound financial stability of the company • Able to provide evidence of relevant insurances
Contractual issues	• Able to work to major forms of Contract Conditions • Able to provide reasonably worded warranties • Able to mobilise to the site in an acceptable period of time

Typical regulatory permits

Permit, licence and/or consent	Issuing body and requirements
Waste Management Licence	
Site licence	• Issued by the Environment Agency • Will also require planning permission • Normally required wherever controlled waste are recovered, treated or disposed on site (also see PPC Permit) • Will be subject to surrender criteria
Mobile plant licence	• Issued by the Environment Agency • Required for most on-site remediation technologies that treat contaminated soils • Requires risk assessment and working plan
Abstraction Licence	• Issued by the Environment Agency • Required where water is to be abstracted from the ground • Likely to place limits on volumes abstracted
Trade effluent discharge consent to foul sewer	• Issued by sewerage undertaker • Likely to place limits on the quantity, quality and/or flow rate of any discharges to the sewer
Discharge Consent to surface waters	• Issued by the Environment Agency • Likely to place limits on the quantity, quality and/or flow rate of any discharges to a watercourse
Groundwater authorisation	• Issued by the Environment Agency • Required to control release of liquids to the ground • Release may not be directly into groundwater
PPC Permit	• Issued by the Environment Agency • Normally required for certain on-site recovery, treatment or disposal activities

Note that work is in hand at the time of publication of the Model Procedures to develop a Single Regeneration Permit in England, which might act alongside or replace some of the above permits and licences.

Design, Implementation and Verification:
Typical content of a verification plan

Figure 4B
OUTPUT 2

O

Typically a verification plan will contain:

- Introductory information (site location, responsible parties for different activities, etc.);
- Background information (e.g., on risk assessment findings, nature of contamination, etc.);
- The scope of remediation to be undertaken to manage the relevant pollutant linkages identified within the conceptual model;
- Critical performance characteristics of each element of remediation that must meet the specification for the remediation to be successful;
- For each element, how 'lines of evidence' can be collected and how performance can be verified. Examples include:
  - Measuring the rates of reaction/degradation of contaminants and the quantities of contaminants/contaminated media removed;
  - Testing soil samples at defined locations, intervals of time, per volume of soil excavated, moved or treated in a process plant for key contaminants that must meet remediation objectives;
  - Measuring concentration of conservative components and/or intermediate or final breakdown products;
  - Testing of quality of imported soils and/or other materials;
  - Testing of water quality after treatment;
  - Measuring the thickness of a capping layer after placement by topographical surveys before and after placement;
  - Measuring the permeability, strength and/or strain at a defined stress of a bentonite and/or cement slurry wall;
  - Visual inspection of gas-resistant membranes laid in composite floor slabs for evidence of tears, gaps around service entries, etc.;
  - Measuring remediation treatment parameters (e.g., pH, dissolved oxygen, election acceptors, injection flow rates)
  - Evidence of conformance to requirements of discharge consents, abstraction licences, etc.
  - Results of nuisance monitoring at site boundaries and other agreed locations (dust, noise, odour, etc.);
  - Testing of water quality in nearby watercourses or groundwater bodies;
  - Compliance testing of stabilised materials.
- For each element, who will be responsible for carrying out measurements or tests, and at what frequency;
- Reporting requirements for all data, including provision of copies of consignment and waste carrier notes for materials being taken to landfill, analytical report sheets, quality assurance information, etc.;
- For remediation where treatment may continue after the initial installation, a decision on the most appropriate time to produce the verification report;
- Proposed response actions if measured data does not conform to specification;
- Schedule of third party contacts, including those to whom verification data should be provided;
- Key criteria that must be met to allow discharge or surrender of regulatory permits or conditions.

Typical content of a monitoring and maintenance plan

Figure 4B
OUTPUT 3
O

A typical monitoring and maintenance plan should include sections dealing with the issues below:

General issues

- Scope of the anticipated monitoring and maintenance work that will be required after completion of remediation
- Proposals for short- and long-term term management of post-completion activities
- Anticipated reporting format, including to whom reports will be made available to

Maintenance issues

- Schedule of regular maintenance activities that will be needed to ensure successful ongoing functioning of remediation (e.g., vegetation clearance to keep vent trenches free of clogging vegetation, calibration and servicing of alarm systems, servicing of pumps and other equipment, replacement of consumables such as activated carbon, etc.)
- Protocols for reactive maintenance
- Proposals for appointing organisation that will be responsible for maintenance work, and how this will be funded
- Proposals for review at defined intervals
- Mechanisms for making decisions about the replacement or upgrading of the remediation if it becomes ineffective, and for liaison with regulators on such decisions

Monitoring issues

- Schedule of regular monitoring that will be needed to ensure successful ongoing functioning of remediation (e.g., monitoring the movement of a LNAPL groundwater plume, monitoring of gas concentrations in boreholes, and monitoring surface water and/or groundwater quality, visual inspection of surface condition of capping layers, etc.)
- Proposals to appoint organisation that will be responsible for monitoring, and how this will be funded
- Definition of response actions in the event that monitoring criteria are exceeded
- Criteria for determining when monitoring can cease

Design, Implementation and Verification:
Typical progress report contents

Figure 4B
OUTPUT 4

O

Explanatory Note

Regular reports on the progress of remediation should be produced by the organisation with responsibility for conducting the work.

Typically, the reports will include the information given below.

- Supervision details
- Progress of activities over time period against programme
- Results of environmental monitoring against agreed environmental standards
- Results of ongoing verification testing against remediation objectives
- Implications for remediation methods and site works in the light of site monitoring and testing
- Identification of any requirements to modify remediation
- Details of any reported health and safety or environmental accidents and/or incidents
- Identification of potential delays
- Details of site visits made by regulators
- Evidence of conformance with regulatory permits and/or licences
- Adequacy of documentary records produced
- Photographic records
- Expenditure over period against budget
- Forecast forward expenditure and implications for budget

Typical content of a verification report

Explanatory Note

Information provided in the verification report should refer to the location of source data or provide such source data as appendices. In particular, all on-site and laboratory analytical data, waste consignment notes, site survey data and as-built drawings should be provided in the appendices. Where the development of a site is phased, separate verification reports may be needed for each phase.

Typically, the verification report should include the material given below.

Report section	Generic content	Examples
Background Information	Reasons and objectives for undertaking the remediation	• Redevelopment • In response to regulatory action
	Site details	• Name and address • Location, including NGR • Site plan and size • Brief history of site and previous uses • Brief summary of any previous investigations • Brief summary of ground and groundwater conditions
	Details of project or related personnel and their roles	• Company names of owner, tenant, contractor(s), developer, consultant(s)
Remediation	Methodology and programme	• Conceptual model to be identifying pollutant linkages to be addressed • General description of remediation • Remediation objectives and remediation criteria agreed • Clear description of the verification plan including the methodologies used for date collection and interpretation • Health and safety issues • Regulatory licences/permits • Site preparation and services • Way-leaves • Sequence of activities • What constitutes completion

(Cont.)

Report section	Generic content	Examples
Remediation (cont.)	Verification	• Volumes and characteristics of material treated • Rate of contaminant mass reduction and/or removal • Volumes, source and quality of imported material • Volumes and characteristics of water and/or liquid waste treated or disposed • Details of encapsulation (including depth and thickness of capping layers) • Details of gas venting • Details of permanent treatment installations • Details of carrier and waste disposal site (consignment note) if material removed off-site • Efficiency of air-scrubbing systems (e.g., percentage efficiency in removing volatile organic compounds) • Zone of influence for in situ venting and/or sparging systems • Details of discharge consents • Quality assurance documentation and warranties from all contractors • Variations (e.g., optimum air injection and/or extraction rates, flow rates)
	Emissions controls monitoring	• Monitoring details for process control purposes • Monitoring details to demonstrate compliance with health, safety or environmental requirements • Monitoring details to check that mitigation measures are working effectively • Monitoring details in support of public relations
	Chemical and physical testing regime	• Chemical testing during the remediation to demonstrate attainment of remediation objectives • Physical testing and measurement during the remediation to demonstrate attainment of engineering objectives on backfilled and/or reused material
	Ongoing monitoring	• Results of surface water, groundwater or soil-gas monitoring to assure the effectiveness of the remediation measures after the remediation has been implemented

(Cont.)

Design, Implementation and Verification:
Typical content of a verification report (Cont.)

Figure 4B
OUTPUT 5

O

Report section	Generic content	Example
Final site conditions	Status at completion	• Description of site conditions
	Final extent of remediation	• Description of final extent of remediation • Implications of final site condition (by extent, depth, etc.) on the future use of the site • A clear statement, based on the presentation of lines of evidence of the extent to which remediation objectives and criteria have been met • Review of conceptual model to demonstrate that all relevant pollutant linkages are managed
	Identification of post-treatment management needs	• Ongoing monitoring needs to establish long-term effectiveness of actions taken • Maintenance requirements to ensure continued working of measures implemented • Administrative controls necessary on land use, maintenance and other building operations • Constraints on future activities (e.g., to avoid damage to capping layers)
Third party contacts	Consultees	• Names, addresses, telephone numbers of utilities, local authority (Environmental Health Office, Planning), Environment Agency, Health and Safety Executive
	Site visits by regulators	• Details of site visits before, during and after remediation by Environment Agency, Environmental Health Officers, Health and Safety Executive and/or Others
	Statutory requirements	• Discharge of planning • Compliance with Remediation Notice • Compliance with Remediation Statement
	Third party agreements	• Details of covenants, way-leaves, warranties • Compliance with other environmental permits

(Cont.)

Typical content of a verification report (Cont.)

Report section	Generic content	Examples
Supporting information	Plans, as-built drawings and photographs	• Photographic records • Plans referenced to Ordinance Survey (OS) Grid showing areas actually remediated, and any areas of residual contamination or sub-surface structures • Plans referenced to OS Grid showing monitoring sample locations
	Test results	• In-situ, on-site and laboratory test results for all materials that are part of the remediated area, including imported materials
	Other documentation	• Health and safety • Quality management systems • Progress reports • Key items of correspondence or meeting minutes • References

Flowchart for Long-term Monitoring and Maintenance

KEY PROCEDURAL POINTS

KP1

Ensure that the plan contains agreed monitoring objectives & criteria

KP2

It may be appropriate to appoint different organisations to deal with monitoring & maintenance

KP3

Ensure that both programmed and reactive maintenance are considered

KP4

Keep the scope of monitoring work under review to ensure it remains valid

KP5

In the event that monitoring objectives have not yet been met, further actions should be implemented

KP6

Copies of reports should be kept by the landowner. Regulators may also require copies

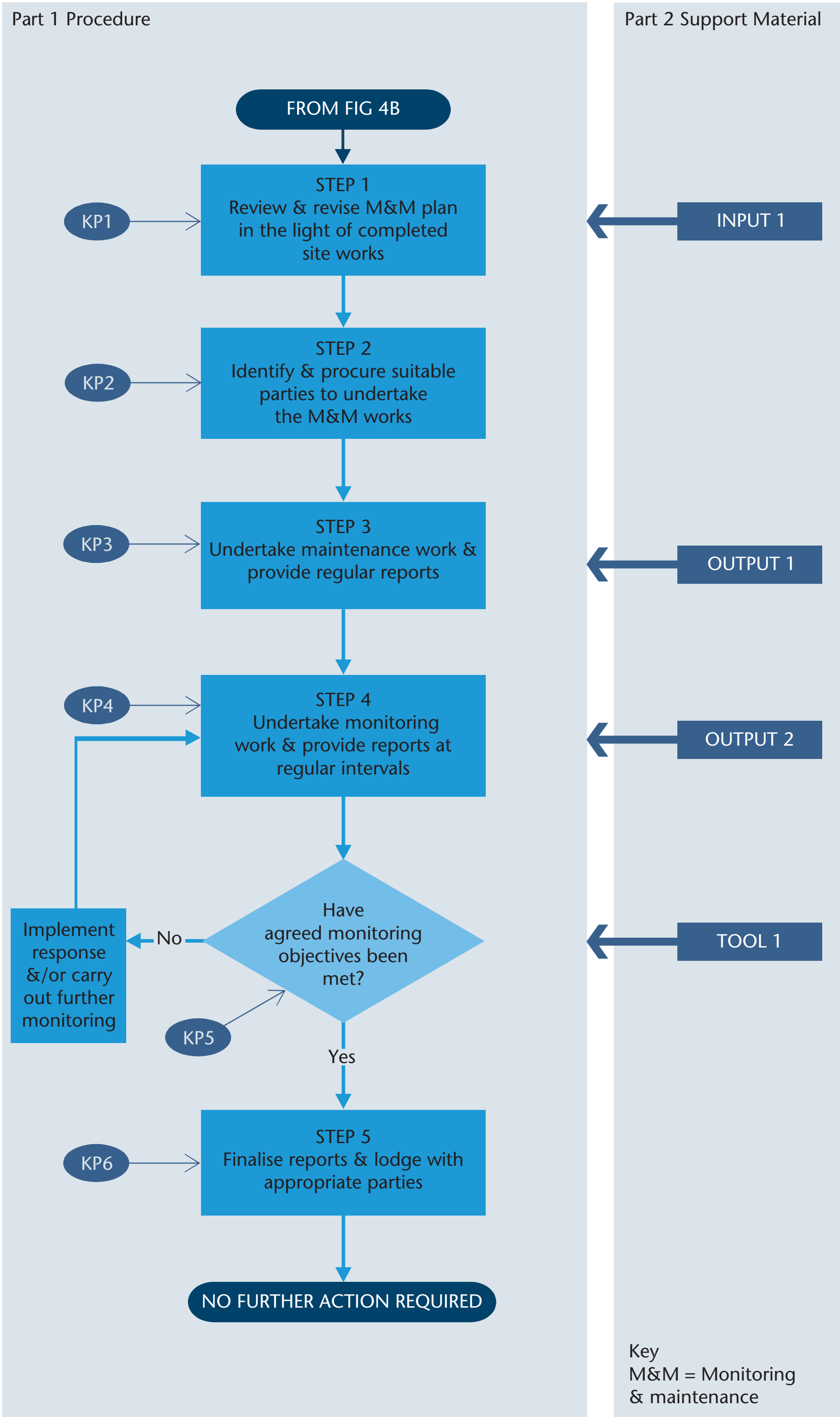

Figure 4C | Long-term Monitoring and Maintenance

Long-term Monitoring and Maintenance (Section 4.4 of Part 1)		
Contents		
INPUTS	INPUT 1	Issues to be considered in revising the monitoring and maintenance plan
TOOLS	TOOL 1	Typical response actions when monitoring criteria are not met
CRITERIA	N/A	
OUTPUTS	OUTPUT 1	Typical contents of a maintenance report
	OUTPUT 2	Typical contents of a monitoring report

II

Long-Term Monitoring and Maintenance:
Issues to be considered in revising the monitoring and maintenance plan

Figure 4C
INPUT 1

I

Explanatory Note

Whilst the need for and scope of monitoring work may be clear on substantial completion of the remediation work, there may be a need for revision and adjustment in the light of emerging data on the performance of the remediation. Issues that may need to be considered are listed below.

Monitoring	• Has scope of remediation changed from the original design? • Does this have implications for scope of monitoring? • What additional monitoring needs to be specified? • Can the additional monitoring be combined with the original scope of work? • Is the frequency and scope of monitoring still relevant to the works? • Are analytical methods and reporting standards agreed? • Has an appropriate organisation been defined to carry out the monitoring? • Are reporting frequencies and content of reports defined? • Are criteria for evaluating monitoring results defined and agreed with the appropriate regulatory bodies? • Are actions defined and agreed in the event that monitoring results do not meet agreed criteria? • Has the dissemination of information been defined?
Maintenance	• Has scope of remediation changed from the original design? • Have land uses remained the same? • Which elements of the overall scheme require maintenance to ensure continued effective functioning? • Does the maintenance require specialist skills? • Can maintenance of the remediation be combined with other site maintenance? • Are there adequate provisions for replacing consumables such as treatment chemicals? • Are power supplies assured and provided with emergency back-up? • Are maintenance work items fully specified in terms of actions, frequency, responsibility and standard to be achieved? • Are reporting and record-keeping requirements defined fully?

Long-Term Monitoring and Maintenance:
Typical response actions when monitoring criteria are not met

Figure 4C
TOOL 1

T

Explanatory Note

The monitoring programme must be accompanied by a set of monitoring criteria. The monitoring and maintenance plan should have identified appropriate response actions that would apply if the monitoring criteria are not met.

Typically appropriate response actions include:

- Verification that monitoring data are correct by checking equipment calibration, calculations, etc.;
- Consider the effect of seasonal variations;
- Consider the effect of spatial variation in monitoring data and whether additional monitoring points should be installed to better define the extent of any problem;
- Increase frequency of monitoring locally or across the whole site;
- Consider the introduction of continuous monitoring or alarm systems;
- Consider the need for the evacuation of buildings;
- Modify the existing remediation to improve effectiveness.

Long-Term Monitoring and Maintenance:

Typical contents of a maintenance report

Figure 4C

OUTPUT 1

O

A typical maintenance report should include sections that deal with:

- Scope of the maintenance work covered by the report;
- Schedule of regular maintenance activities carried since the previous report;
- Report on exceptional work items undertaken since the previous report;
- Report on condition of the remediation;
- Information on use of consumables, energy, etc.;
- Requirement to action repairs or to service plant;
- Recommendations for future routine or exceptional work items.

Long-Term Monitoring and Maintenance:
Typical contents of a monitoring report

Figure 4C
OUTPUT 2

O

A typical monitoring report should include sections that deal with:

- Scope of the monitoring work covered by the report;
- Schedule of regular monitoring activities carried out since the previous report;
- Report on visual inspection, monitoring and test results, including exceptional results recorded since the previous report;
- Assessment of compliance against previously agreed criteria;
- Report on any actions taken in response to exceptional results;
- Recommendations for future monitoring and any variations to the agreed monitoring programme;
- Supporting information, including sampling, analytical and quality assurance procedures used, type of equipment, calibration records, location and construction of monitoring points.

III

Part 3 – Information Map

III

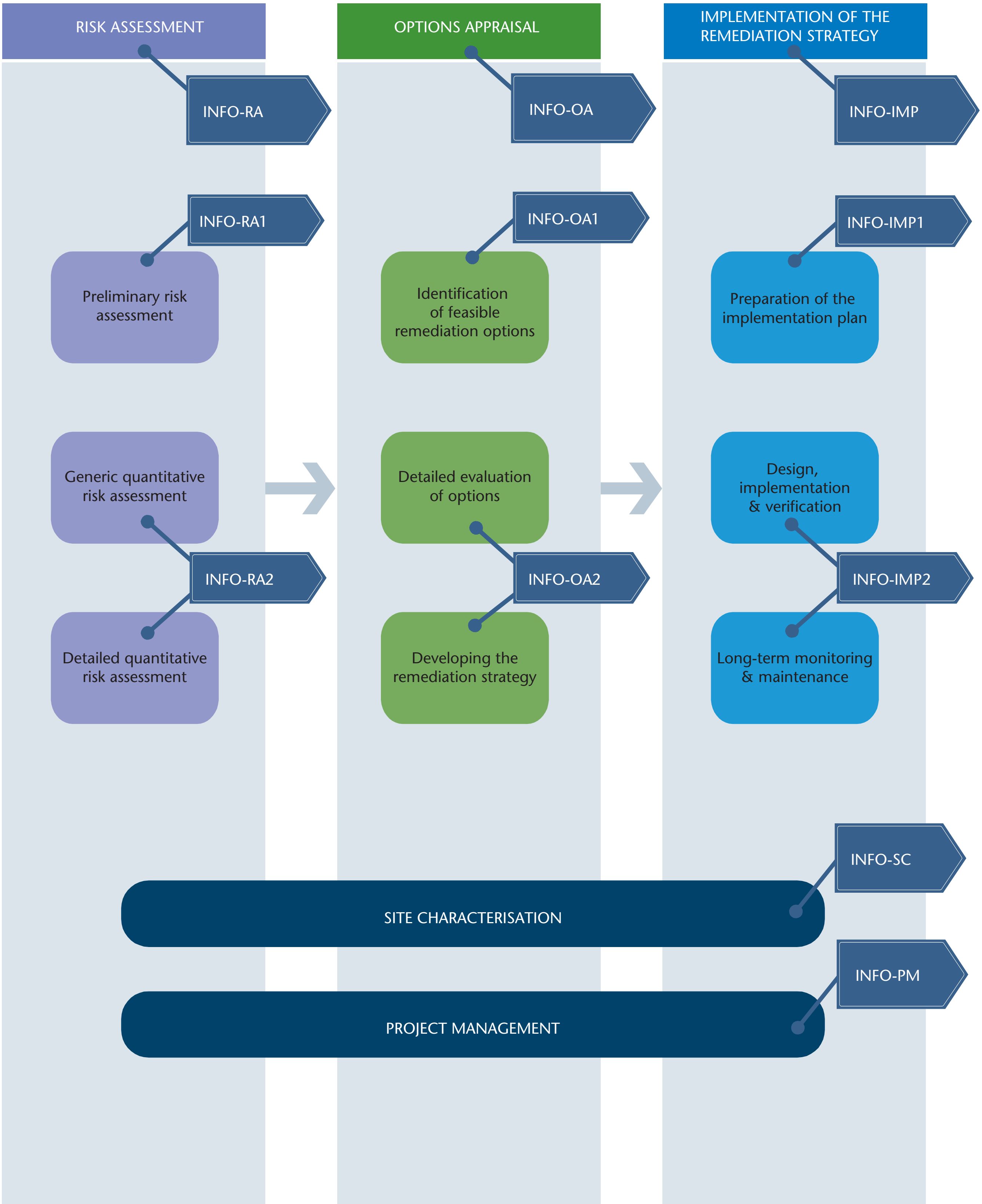

Figure 5 | Schematic of the Land Contamination Information Map

Introduction to Part 3

The Information Map provides details of over 80 individual or sets of key publications that contain more detailed technical guidance on particular aspects of the risk management process. All the documents have been issued by authoritative bodies, such as the Department for Environment, Food and Rural Affairs (Defra) and its predecessor departments, the Environment Agency, the British Standards Institution and others.

Each entry in the Information Map sets out the title, date, report reference and publisher of the document or document set and its current status (published or in preparation). Contact details for copies of documents are also provided - the bold letter by each entry refers to the entries in both the Abbreviations List and the Issuing Body Contact Details at the back of Part 3.

All the information sources listed are relevant to a good understanding of risk management in land contamination applications, but the Information Map is not exhaustive and other documents may be useful for certain users in particular circumstances. Readers should also be aware that information and guidance on land contamination are published and revised on a regular basis, and they should ensure that the most up-to-date publications and information are referenced.

INFO-RA Key Information Sources: Risk Assessment

Risk assessment – preliminary INFO-RA1

Risk assessment – generic and detailed quantitative assessment INFO-RA2

General INFO-RA2-1

Assessing risks to human health INFO-RA2-2

Assessing risks to the water environment INFO-RA2-3

Assessing risks associated with gases and vapours INFO-RA2-4

Assessing risks to ecosystems INFO-RA2-5

Assessing risks to buildings and services INFO-RA2-6

INFO-OA Key Information Sources: Options Appraisal

Identification of feasible remediation options — INFO-OA1

Detailed evaluation of remediation options — INFO-OA2

Developing the remediation strategy — INFO-OA2

INFO-IMP Key Information Sources: Implementation of the Remediation Strategy

Planning	INFO-IMP1
Implementation, verification and monitoring	INFO-IMP2
Long term monitoring and maintenance	INFO-IMP2

INFO-SC Key Information Sources: Site Characterisation

General	INFO-SC1
Sampling design	INFO-SC2
Field and laboratory analysis	INFO-SC2

III

INFO-PM Key Information Sources: Project Management

Guidance specific to particular industrial or commercial sectors — INFO-PM1

Health and safety and quality management — INFO-PM1

Communication — INFO-PM3

INFO-RA1		Key Information Sources: Preliminary Risk Assessment
INFO-RA1a	**DoE, 1994** ● **A**	**Documentary Research on Industrial Sites, CLR 3** Contains detailed advice on how to conduct desk-based research of documentary records, such as maps and directories, when assessing the development history of land. Includes details on sources of relevant information and advice on interpretation.
INFO-RA1b	**DoE, 1995** ● **B**	**Industry profiles (various titles)** A comprehensive set of individual booklets that contain information on a wide range of industrial processes and activities that may have lead to land contamination. Each booklet contains information on; the development of the industrial sector, including likely or typical geographical location, type of processes carried out, type of materials and substances handled and the possible distribution of hazardous materials that result from handling raw, process and waste materials.
INFO-RA1c	**DoE, 1994** ● **A**	**Information Systems for Land Contamination, CLR 5** Contains advice on the management of information on land contamination with particular emphasis on the use of computer-based systems. Issues covered include: • What type of information needs to be managed; • How to organise and manage information, including storage and presentation, accessibility, maintenance of records, integration, quality control and security; • Advice on different types of information technology.
INFO-RA1d	**EA, 2001** ● **C**	**Technical Guidance on Special Sites** Technical guidance to assist in the identification of particular categories of land that (if it is contaminated land) may be a special site. Series of 7 documents: › MOD Land (P5-042/TR/01); › Chemical Weapons Sites (P5-042/TR/02); › Explosives Manufacturing and Processing (P5-042/TR/03); › Acid Tar Lagoons (P5-042/TR/04); › Petroleum Refineries (P5-042/TR/05); › Nuclear Establishments (P5-042/TR/06). (Cont.)

III

INFO-RA1		Key Information Sources: Preliminary Risk Assessment (Cont.)
INFO-RA1e	EA, 2001	**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, NC/99/38/2**
	● C	This document provides guidance on good practice in the development of conceptual models that should form the basis of risk assessments. It also considers a phased approach on the application of mathematical models to contaminant transport problems in moving from simple calculations to analytical models and finally to numerical models, if required.
INFO-RA1f	DEFRA/EA, 2002	**Potential Contaminants for the Assessment of Land, CLR 8**
	● C/D	Provides information on a wide selection of hazardous substances that are commonly encountered in contaminated sites in the UK. Also contains a matrix that shows which substances have the potential to impact specific receptors, and summarises the main characteristics and hazardous properties of those substances.
INFO-RA1g	DEFRA 2004	**Letter From MAFF to Part IIA Authorities, CLAN 4 – 04**
	● D	This paper provides guidance for those situations where contamination may be present in soils being used for commercial food production, either by growing crops or by livestock, and how it may be dealt with under Part IIA.

INFO-RA2-1		Key Information Sources: Risk Assessment – General
INFO-RA2-1a	EA, 2000	**Land Contamination Risk Assessment Tools: An Evaluation of Some of the Commonly Used Methods, R&D Technical Report, P260**
	● C	Presents the findings of a research project to benchmark risk assessment models and risk-ranking tools commonly used for risk-based decision processes in land contamination applications. This report describes the models such that current and potential users understand their logic, characteristics and approaches to risk assessment. In operating the models in default mode and also with data relating to ten representative sites (based on types of contaminant problems), the report also demonstrates how the different models may perform.
INFO-RA2-1b	EA, 2002	**Information on Land Quality: Sources of Information (Including Background Contaminants)**
	● C	Report that provides an overview of (a) sources of information on land contamination in the UK and (b) data sets that may be used to interpret background concentrations of contaminants in soil. Both organic and inorganic substances are considered. The report is presented in 4 volumes: › England (TR P291); › Wales (TR P292); › Scotland (TR P293); › Northern Ireland (TR P294).
INFO-RA2-1c	EA, 2003	**Risk Assessment Fact Sheets:** **FS-01 Fact Sheet for the SNIFFER Framework** **FS-02 Fact Sheet for the RBCA Tool Kit for Chemical Releases** **FS-03 Fact Sheet for RISC-HUMAN (3.1)** **FS-04 Fact Sheets for RISC** **FS-05 Fact Sheet for Risk* Assistant (1.1)** **FS-06 Fact Sheet for the Contaminated Land Exposure Assessment (CLEA) 2002 Model**
	● C	The purpose of these fact sheets is to provide users with: • A brief description of the selected model (including receptor types, land use and exposure scenarios); • An overview of the model's principal features (including what the model is supposed to do, model usability, toxicological information, contaminants, receptor characterisation, land use, pathway characterisation); • Description of model outputs and interpretation; • Impacts of sensitive model parameters; • Common problems and mistakes; • Model limitations – what the model does not do. (Cont.)

III

INFO-RA2-1	Key Information Sources : Risk Assessment – General (Cont.)	
INFO-RA2-1d	**EA, 2004** ● **C**	**A Guide to Using Soil Guideline Values (SGVs)** This fact sheet considers the following questions: What are soil guideline values? What is an 'intervention value'? Under what circumstances should SGVs be used? What is the difference between Generic Assessment Criteria (GAC), and Site-Specific Assessment Criteria (SSAC)? Are SGVs remediation targets? When is a SGV appropriate for my site? What can I do if a SGV has not been published for my contaminant of interest? Are values generated by third parties (using the CLEA 2002 model or commercially available models) the same as SGVs?
INFO-RA2-1e	**ASTM, 1995** ● **E**	**Standard Guide for Risk-based Corrective Action Applied at Petroleum Release Sites, E 1739–95** This American Standard is a guide to risk-based corrective action (RBCA) on petroleum releases to the environment. It sets out a tiered methodology to assess and respond to potential human health and environmental risks consistent with the approach recommended by the United States Environmental Protection Agency.
INFO-RA2-1f	**ASTM, 2000** ● **E**	**Standard Guide for Risk-based Corrective Action, E2081–00** This report is a development of the 1995 standard that extends the RBCA framework to cover a wide range of substances (not just petroleum related) and offers the potential to incorporate ecological risk assessment techniques.

INFO-RA2-2	Key Information Sources: Risk Assessment – Human Health	
INFO-RA2-2a	**DEFRA/EA, 2002** ● **C/D**	**Overview of the Development of Guideline Values and Related Research, CLR 7** Summarises the scope of current and proposed technical guidance on the assessment of contaminated land. Also describes the relationship between various guidance documents.
INFO-RA2-2b	**DEFRA/EA, 2002** ● **C/D**	**Contaminants in Soils: Collation of Toxicological Data and Intake Values for Humans. Consolidated Main Report, CLR 9** Describes the key elements of the UK approach to assessment of the human toxicology of exposure to hazardous substances in the environment and the derivation of Tolerable Daily Intake values for priority contaminants. The report includes a review of the approach taken by other authorities in this area, and considers key issues, such as background intakes of contaminants from sources other than soils, dealing with mixtures of contaminants and how the risks associated with carcinogenic substances have been handled.
INFO-RA2-2c	**DEFRA/EA, 2002** ● **C/D**	**The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms, CLR 10** Describes the exposure model (CLEA) used by the UK authorities to derive UK Guideline Values for contaminants in soils and sets out all the relevant background research. This includes a discussion of the pathways used in CLEA, and selection of exposure equations, receptor characteristics and probability density functions for the Monte Carlo routine.
INFO-RA2-2d	**DEFRA/EA 2002** ● **C/D**	**Contaminants in Soils: Collation of Toxicological Data and Intake Values for Humans, TOX series** Substance-specific documents that summarise the human toxicology of individual substances and provide recommendations on an appropriate Tolerable Daily Intake Value. These recommendations form the basis for the derivation of the UK Guideline Values for contaminants in soils. (Cont.)

INFO-RA2-2	Key Information Sources: Risk Assessment – Human Health (Cont.)	
INFO-RA2-2e	DEFRA/EA, 2002 ● C/D	**Guideline Values for Contaminants in Soils, SGV series** Substance-specific documents that detail the UK Guideline Values for contaminants in soils. Each document contains: • Introductory material on the derivation of Soil Guideline Values; • Summary information on the occurrence of the substance in the environment; • Summary information on the relevant health effects; • The value (e.g., Tolerable Daily Soil Intake, TDSI) used to derive the Soil Guideline value; • The pathways used to calculate the Guideline Value for that substance; • The Guideline Value for that substance for each relevant land-use scenario; • A breakdown of the contribution to the Guideline Values made by each pathway; and, where appropriate, • The effect on Guideline Values of site-specific factors such as pH and soil organic matter.
INFO-RA2-2f	EA, 2002 ● C	**Measurement of Bioaccessibility of Arsenic in UK Soils, P5-062/TR02** Report on a study to assess the robustness of a Physiologically Based Extraction Test (PBET) to estimate the oral bioaccessibility of arsenic in soil. The study examined soils that contained arsenic at concentrations >20 mg/kg collected from three study areas in England. The report contains details of the methods used to determine the major and trace element composition of soils, arsenic bioaccessibility and other relevant soil parameter measurements.
INFO-RA2-2g	SNIFFER, SEPA, EA 2003 ● C/Q	**Method for Deriving Site-specific Human Health Assessment Criteria for Contaminants In Soils, LQ01** Describes a method for deriving site-specific assessment criteria (SSAC) for use when considering the risk to human health from chronic exposure to heavy metals (except lead), metalloids and organic substances in soils. The method uses a risk-based source–pathway–receptor pollutant linkage framework and deterministic methodology. Exposure pathways include: direct ingestion of soil and dust, consumption of home-grown or allotment vegetables, ingestion of soil attached to vegetables, inhalation of soil vapours outdoors and inhalation of soil vapours indoors. A test for the significance of the dermal pathway is introduced. A sensitivity analysis for the method is also included. (Cont.)

INFO-RA2-2	Key Information Sources: Risk Assessment – Human Health (Cont.)		
INFO-RA2-2h	EA (In prep) o C		**Human Health Risk Assessment – Detailed Quantitative Risk Assessment** This document aims to provide a methodology (consistent with CLR 7-11) that supports quantitative risk assessment by deriving SSAC to assess chronic risks to human health from land contamination.
INFO-RA2-2i	TPHCWG, 1998 ● N		**Petroleum Hydrocarbon Analysis of Soil and Water in the Environment, Volume 1** First in a series of five documents produced by the US Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) to develop a standardised approach to the classification, characterisation and assessment of sites contaminated by petroleum hydrocarbons, including fuels, lubricating oils and crude oils. Volume 1 discusses analytical methods to quantify total petroleum hydrocarbon (TPH), petroleum mixtures and other hydrocarbon constituents in soil and water samples.
INFO-RA2-2j	TPHCWG, 1998 ● N		**Composition of Petroleum Mixtures, Volume 2** Second in the TPHCWG series, Volume 2 provides a thorough compilation of composition data for a range of petroleum products.
INFO-RA2-2k	TPHCWG, 1997 ● N		**Selection of Representative TPH Fractions Based on Fate and Transport Considerations, Volume 3** Third in the TPHCWG series, Volume 3 defines fractions of TPH expected to behave similarly in the environment. Identification of these fractions simplifies the analysis of environmental samples, fate and transport modelling and risk assessment at petroleum release sites.
INFO-RA2-2l	TPHCWG, 1997 ● N		**Development of Fraction-specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for TPHs, Volume 4** Fourth in the TPHCWG series, Volume 4 provides the technical basis for the development of TPH faction RfDs and RfCs for use in risk assessment.
INFO-RA2-2m	TPHCWG, 1999 ● N		**Human Health Risk-based Evaluation of Petroleum Release Sites: Implementing the Working Group's Approach, Volume 5** Fifth in the TPHCWG series, Volume 5 integrates the findings of Volumes 1 to 4 of the series into the development of remedial goals at petroleum release sites.

INFO-RA2-3	Key Information Sources: Risk Assessment – Water Environment		
INFO-RA2-3a	**DoE, 1994**		**A Framework for Assessing the Impact of Contaminated Land on Groundwater and Surface Water, 2 Volumes, CLR 1**
	●	**A**	Sets out a framework to assess the potential impact of contaminated sites on the water environment. It includes a qualitative assessment step and an introduction to quantitative techniques for predicting impacts on surface and groundwater quality. Volume 2 contains guidance sheets for each element of the assessment methodology and model assessment plans for different types of application.
INFO-RA2-3b	**EA, 1998**		**Policy and Practice for the Protection of Groundwater (Second Edition)**
	●	**C**	This document details how the Agency will meet its statutory responsibilities for the protection and conservation of groundwater resources. In particular, it aims to ensure that all risks to groundwater resources, both point source and diffuse, are dealt with in a common framework, and provides a common basis for decisions that affect groundwater resources within and between its regions.
INFO-RA2-3c	**EA, 1999**		**Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources, R&D Publication 20**
	●	**C**	Sets out the Environment Agency's recommended approach for assessing the risks associated with contaminated land (and other potentially polluting events and activities) on the water environment. The approach incorporates a tiered assessment that becomes progressively more sophisticated and demanding in terms of site characterisation data, but allows assessors to reach increasingly less 'conservative' assessment outcomes.
INFO-RA2-3d	**EA, 2002**		**Guidance on the Assessment and Interrogation of Subsurface Analytical Contaminant Fate and Transport Models, NC/99/38/1**
	●	**C**	This document provides guidance on the assessment and interrogation of subsurface analytical contaminant transport models. Checklists of, "what to look for", are provided to enable easy and systematic assessment at all stages of the modelling process.
INFO-RA2-3e	**EA, 2002**		**Environment Agency Technical Advice to Third Parties on Pollution of Controlled Waters for Part IIA of the Environmental Protection Act 1990, No 07/02**
	●	**C**	Describes the Agency's recommended approach for prioritising the inspection of sites that may pose a threat to controlled waters and the Agency's interpretation of the definition of special sites made under regulations 2 and 3 of the Contaminated Land (England) Regulations 2001. Contains a useful summary (current at the time of publication) of water quality criteria.

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INFO-RA2-3	Key Information Sources: Risk Assessment – Water Environment (Cont.)	
INFO-RA2-3f	**EA, 2003** ● C	**ConSim (Release 2): Contamination Impact on Groundwater: Simulation by Monte Carlo Method** ConSim is a software tool designed to assess risks posed to groundwater by leaching contaminants. It is a probabilistic methodology that takes account of contaminant mobilisation and transport. It adopts a tiered approach based on that in the Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources.
INFO-RA2-3g	**EA, 2004** ● C	**An Illustrated Handbook of DNAPL Transport and Fate in the Subsurface, R&D Publication 133** This handbook provides an overview of the nature of dense non-aqueous phase liquid (DNAPL) contamination in a UK context. It is intended to inform those involved with site investigations, risk assessments and the selection and implementation of remediation strategies.

III

INFO-RA2-4	Key Information Sources: Risk Assessment – Gases and Vapours	
INFO-RA2-4a	BRE, 1991 • B	**Construction of New Buildings on Gas-contaminated Land, BR212** Contains basic technical advice on the design of gas-protection measures for new buildings on land affected by hazardous gases, such as methane.
INFO-RA2-4b	CIRIA, 1993 • F	**Methane: Its Occurrence and Hazards in Construction, R130** Reviews all aspects of methane generation and associated hazards, including factors relevant to methane generation and migration, and the circumstances in which methane may present a threat to the built environment.
INFO-RA2-4c	CIRIA, 1995 • F	**Protecting Development from Methane, R149** Contains similar, but more detailed, advice than the BRE document (see INFO-RA2-4a) and includes case studies of practical design measures in different applications. It also provides a categorisation scheme for sites that have different gassing regimes. (See also Wilson SA and Card GB, Reliability and risk in gas protection design, Ground Engineering, February 1999 and clarification article in the News Section of Ground Engineering, March 1999).
INFO-RA2-4d	CIRIA, 1995 • F	**Interpreting Measurements of Gas in the Ground, R151** Contains advice on the interpretation of the results of ground gas investigations, including in-situ and laboratory testing and the effect of such factors as temperature and pressure, fluctuating groundwater levels, etc.
INFO-RA2-4e	CIRIA, 1995 • F	**Risk Assessment for Methane and Other Gases from the Ground, R152** Sets out a risk assessment procedure that incorporates both qualitative and quantitative assessment techniques. The quantitative methodology uses fault-tree analysis to predict the probability of an unacceptable outcome (such as an explosion) by assigning probabilities to various components of the source–pathway–receptor relationship (e.g., the potential for gas generation and/or migration, failure of a membrane, presence of an ignition source, etc.).
INFO-RA2-4f	DETR/PIT, 1997 • G	**Passive Venting of Soil Gases Beneath Buildings, Volume 1 (Guide for Design) and Volume 2 (Computational Fluid Dynamics Modelling: Example Output)** Sets out a methodology to assess the risks to buildings posed by soil gases, and to design appropriate passive gas venting measures. (Cont.)

INFO-RA2-4	Key Information Sources: Risk Assessment – Gases and Vapours (Cont.)	
INFO-RA2-4g	**IWM, 1998**	**The Monitoring of Landfill Gas, Landfill Gas Monitoring Working Group Report**
	● **S**	Guidance that describes methodologies and techniques used to monitor the quantity and composition of landfill gas at source.
INFO-RA2-4h	**EA, 2002**	**Vapour Transfer of Soil Contaminants, R&D Technical Report, P5-08/TR**
	● **C**	Provides guidance on the suitability of models used to predict human exposure to contaminants in soils by the movement of vapours and gases through soils and into buildings. In addition, it considers the choice of models and input parameter values used in the CLEA model and the derivation of guideline values.

INFO-RA2-5	Key Information Sources: Risk Assessment – Ecological Systems	
INFO-RA2-5a	**EA, 2002** ● C	**Assessing Risks to Ecosystems from Land Contamination, R&D Technical Report P299** Sets out a UK framework for assessing the risks to ecosystems from land contamination, based on a review of international approaches, including those used in the US, Australia, Canada and the Netherlands. This methodology proposes a three-tier approach to data gathering, understanding the problem and assessing hazards and risks on a weight-of-evidence basis.
INFO-RA2-5b	**EA, 2002** ● C	**Review of Sublethal Ecotoxicological Tests for Measuring Harm in Terrestrial Ecosystems, P5-063/TR1** Report presents a review, and recommends sub-lethal ecological tests to assess harm to terrestrial ecosystems.
INFO-RA2-5c	**EA, 2003** o C	**Ecological Risk Assessment, R&D Technical Report P5-069/TR1** This is a public consultation that describes a tiered ecological risk assessment framework and methodologies used to assess harm to ecosystems from contaminants in soils.
INFO-RA2-5d	**EA, 2004** ● C	**Soil Screening Values for use in Ecological Risk Assessment, R&D Technical Report P5-091/TR** This report presents a review of leading international approaches to setting soil screening values that are used in environment risk assessment. It recommends an approach for developing soil screening values that may be used in the Environment Agency's Ecological Risk Assessment (ERA) framework (R&D Technical Report P5-069/TR1 – INFO-RA2-5c).

INFO-RA2-6	Key Information Sources: Risk Assessment – Buildings and Services	
INFO-RA2-6a	**BRE, 1994** ● **B**	**Performance of Building Materials in Contaminated Land, BR255** Explores the mechanisms responsible for common causes of materials failure due to contact with contaminants and/or contaminated ground, and provides general technical guidance on the susceptibility of a range of material types, including concrete, metals, plastics, rubbers, asbestos cement and brickwork.
INFO-RA2-6b	**EA, 2000** ● **C**	**Risks of Contaminated Land to Buildings, Building Materials and Services: A Literature Review, Technical Report P331** Provides a review of information relating to the hazards and risks to buildings, other structures and services that arise from the presence of ground conditions aggressive to building materials, combustible fill, potentially volume-unstable blast-furnace and steelmaking slags, and fill or made ground liable to settlement. The information is presented for use in a risk assessment framework.
INFO-RA2-6c	**EA, 2001** ● **C**	**Guidance on Assessing and Managing Risks to Buildings from Land Contamination, Technical Report P5 035/TR/01** Provides guidance on the assessment and management of risks to buildings, other structures and services that arise from the presence of ground conditions aggressive to building materials, combustible fill, potentially volume-unstable blast-furnace and steelmaking slags, and fill or made ground liable to settlement. The document is intended for use both where new construction is to take place and where it is suspected that existing buildings, materials and services may be at risk.
INFO-RA2-6d	**ODPM, 2004** ● **T**	**Approved Document C – Site Preparation and Resistance to Contaminants and Moisture** Provides practical guidance on dealing with contamination hazards in the context of construction activities on land affected by contamination as required by the Building Regulations 2000 (SI 2000/2531) in England and Wales.

INFO-OA1	Key Information Sources: Options Appraisal – Identification of Feasible Remediation Options	
INFO-OA1a	**CIRIA, 1995** • **F**	**Remedial Treatment for Contaminated Land, SP 104, Classification and Selection of Remedial Methods** Sets out a classification system for remedial methods based on the scientific principles involved, mode of operation (in situ or ex situ) and media type. Also contains summary information on different treatments and a methodology to evaluate different remedial methods as part of the process of developing an appropriate remediation strategy.
INFO-OA1b	**EA, 2000** • **C**	**Assessing the Wider Environmental Value of Remediating Land Contamination: A Review, R&D Technical Report, P238** Describes the individual effects that may be considered within an assessment of the wider environmental effects of remediation. The assessment is described in terms of seven broad themes that cover: • Aggravation factors; • Air and atmosphere; • Water function; • Ground function; • Legacy; • Resource and energy utilisation; and • Conservation.
INFO-OA1c	**EA 2001** • **C**	**Remedial Treatment Action Data Sheets** Series of fact sheets that contain concise and authoritative information on techniques for the remediation of contaminated soils and groundwater, taking into account commercial availability and track record in England and Wales. Six fact sheets are currently available: › Biopiles (DS-01); › Windrows (DS-02); › Land farming (DS-03); › Monitored natural attenuation (DS-04); › Bioventing (DS-05); › Cement-based stabilisation and solidification (DS-015). (Cont.)

INFO-OA1	Key Information Sources: Options Appraisal – Identification of Feasible Remediation Options (Cont.)	
INFO-OA1d	**EA, 2000** • C	**Guidance on the Assessment and Monitoring of Natural Attenuation of Contaminants in Groundwater, R&D Publication 95** This technical guidance provides a framework to assist good practice in the design, evaluation and implementation of natural attenuation strategies for groundwater within a risk-based context in the UK. Generic guidance is provided on procedures to assess the viability of natural attenuation, to demonstrate that natural attenuation is occurring, to evaluate the longer-term attenuation capability and to verify attainment of the agreed remediation objectives.
INFO-OA1e	**EA, 2001** • C	**Source Treatment for Dense Non-aqueous Phase Liquids, R&D Technical Report P5-51/TR/01** This report presents the options currently available to remediate dense non-aqueous phase liquids (DNAPL) source zones that lie beneath the water table. Each remediation strategy is discussed in terms of its principles, case studies, advantages and disadvantages, current status and the UK context. It also recommends future research that would help to establish the effectiveness of technologies in the field.
INFO-OA1f	**EA, 2002** • C	**Guidance on the Use of Permeable Reactive Barriers for Remediating Contaminated Groundwater NC/01/51** This document sets out generic guidance for the design, construction, operation and monitoring of permeable reactive barriers for the treatment of contaminated groundwater.
INFO-OA1g	**EA, 2004** • C	**Guidance on the Use of Stabilisation/Solidification for the Treatment of Contaminated Soil, R&D Technical Report P5-064/TS** This document presents a framework for the design and implementation of stabilisation and/or solidification treatments for contaminated soils or other waste streams.

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INFO-OA2	Key Information Sources: Options Appraisal – Detailed to Evaluation of Options	
INFO-OA2a	**BRE, 1994** ● **B**	**Slurry Trench Cut-off Walls to Contain Contamination, Digest 395** Considers two forms of cut-off wall: slurry trench walls and cement–bentonite cut-off walls with geomembranes. The material characteristics of cement–bentonite slurries and geomembranes are discussed, along with design specifications and mix proportions.
INFO-OA2b	**CIRIA, 1995** ● **F**	**Remedial Treatment for Contaminated Land, SP 105 – SP 109** Vol V Excavation and Disposal; Vol VI Containment and Hydraulic Measures; Vol VII Ex-situ Remedial Methods for Soils, Sludges and Sediments; Vol VIII Ex-situ Remedial Methods for Contaminated Groundwater and Other Liquids; Vol IX In-situ Methods of Remediation. Five volumes that contain comprehensive descriptions of a broad selection of different remedial techniques. Technical content covers: • Technical and scientific basis; • Applicability (to specific contaminants); • Planning and operational requirements; • Effectiveness, limitations and costs.
INFO-OA2c	**BRE, 1995** ● **B**	**Polymeric Anti-corrosion Coatings for Protection of Materials in Contaminated Land, BR286** Contains recommendations for the protection of service and construction materials for use in contaminated ground.
INFO-OA2d	**CIRIA, 1996** ● **F**	**Barriers, Liners and Cover Systems for Containment and Control of Land Contamination, SP124** Builds on CIRIA SP106 (Containment and Hydraulic Measures) and contains more detailed technical guidance on the design and implementation of physical containment measures in land contamination applications.
INFO-OA2e	**DETR,1998** ● **G**	**Active Containment: Combined Treatment and Containment Systems** Discusses the prospects for the use of active containment technologies, for the treatment of contaminated materials. Reviews international state-of-the-art active containment based on a literature survey. (Cont.)

INFO-OA2	Key Information Sources: Options Appraisal – Detailed Evaluation of Options (Cont.)		
INFO-OA2f	**EA, 1999**		**Costs and Benefits Associated with the Remediation of Contaminated Groundwater: A Review of the Issues, R&D Technical Report P278**
	•	**C**	This report provides a fundamental review of the costs and benefits of remediation of groundwater pollution. This includes a review of current thought on how groundwater contributes to human welfare, and the practical implications of considering costs and benefits. It considers the state of current practice in cost–benefit analysis of groundwater contamination, and reviews the issues that relate to the degree to which groundwater should be remediated.
INFO-OA2g	**EA, 2000**		**Costs and Benefits Associated with the Remediation of Contaminated Groundwater: A Framework for Assessment, R&D Technical Report P279**
	•	**C**	This report sets out a framework to take account of the likely costs and benefits associated with groundwater remediation. It considers where compliance should be evaluated as part of the risk assessment process and the most cost-effective manner to control the unacceptable risks.
INFO-OA2h	**EA, 2000**		**Cost–Benefit Analysis for Remediation of Land Contamination, R&D Technical Report P316**
	•	**C**	This technical document describes a framework used to compare the relative cost and benefits of two or more options for remediation at a contaminated site. It is suitable for assessing the relative differences in the costs and benefits associated with remedial techniques for contaminated soil and/or groundwater.
INFO-0A2i	**CIRIA, 2001**		**Remedial Processes for Contaminated Land – Principles and Practice, C549**
	•	**F**	Provides guidance on the selection, design, commissioning, operation, monitoring and verification of technologies for the remediation of land affected by contamination.

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INFO-OA2	Key Information Sources: Options Appraisal – Detailed to Evaluation of Options (Cont.)		
INFO-OA2j	CIRIA, 2002		**Biological Methods for the Assessment and Remediation of Contaminated Land: Case Studies, C575**
	•	F	Provides guidance on the selection and performance of biological test methods to assess levels of contamination in soils and water. In addition, it describes bioremediation technologies suitable for treating contaminated soils and waters.
INFO-OA2k	EA 2002		**Costs and Benefits Associated with the Remediation of Contaminated Groundwater: Application and Example, R&D Technical report P2-078/TR**
	•	C	This document illustrates the application of the cost–benefit analysis (CBA) framework described in R&D report P279 (INFO-OA2g). The example, in this study involves a complex site and complex contamination problems. It demonstrates how the techniques of CBA can be used to assist decision making for groundwater remediation.
INFO-OA2l	EA, 2002		**Laboratory to Field-scale Relationships in the Assessment of the Potential for Monitored Natural Attenuation of Contaminants in Groundwater, R&D Technical Report P2-254/TR**
	•	C	The report considers the measurements and interpretation of laboratory data when assessing monitored natural attenuation (MNA) in groundwater. "Rules of thumb" to use when translating laboratory data to the field are described.
INFO-OA2m	CIRIA, 2003		**Non-biological Methods for the Remediation of Contaminated Land: Case Studies, C588**
	•	F	This report describes a number of physical, chemical, stabilisation and thermal remedial treatments and includes a series of case studies that illustrate their application to both radionuclide and non-radionuclide problems in the UK.

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INFO-OA2	Key Information Sources: Options Appraisal – Detailed to Evaluation of Options (Cont.)	
INFO-OA2n	**CL:AIRE** **● R**	Provides a range of publications on different aspects of remediation, for example: **Technology Demonstration Project Reports** › Field Trial of Low Temperature Thermal Desorption Technology, TDP1; › Remediation of Basford Gasworks Using Soil Washing, TDP2; › Design, Installation and Performance Assessment of a Zero Valent Iron Permeable Reactive Barrier in Monkstown, Northern Ireland, TDP3; › Slurry Phase Bioreactor Trial, TDP4; › Solid Phase Bioremediation Trial at Avenue Coking Works, TDP6; › Design, Installation and Performance Assessment of an Air Sparge Barrier System, TDP9. **Case Study Bulletins** › A Constructed Wetland to Treat Acid Mine Drainage from Colliery Spoils at Quaking Houses, County Durham, CSB2; › Wheal Jane Tin Mine, Cornwall, CSB3; › Pumpherston Tar Stabilisation, CSB4. **Research Bulletins** › Enhanced In Situ Bioremediation Technique for Manganese Removal from Mine Waters, RB1; › A Novel Electrokinetic Technique for Soil Remediation and Engineering, RB2. **Technical Bulletins** › A Process for Conducting Field Trials to Evaluate Remediation Technologies, TB6.
INFO-OA2o	**EA (in prep)** **o C**	**Guidance on treatability studies for permeable reactive barriers (PRBs)** This report describes a generic framework for designing and implementing treatability studies for permeable reactive barriers (PRBs) that includes a literature review of the key reactive processes, reactive media used in laboratory trials, pilot studies and full-scale PRBs, and potential problems that should be considered in designing an effective system.

III

INFO-IMP1	Key Information Sources: Implementation of the Remediation Strategy – Planning		
INFO-IMP1a	**ICE, 1994**		**Design and Practice Guide – Contaminated Land: Investigation, Assessment and Remediation**
	●	**H**	Provides a relatively succinct description of the main technical principles that underlie the process of managing contaminated land including planning and designing remediation projects. Note that since publication of this document, further development of risk assessment and risk management terminology has taken place.
INFO-IMP1b	**CIRIA, 1995**		**Remedial Treatment for Contaminated Land, SP 111, Volume xi, Planning and Management**
	●	**F**	Sets out the key issues involved in planning and managing remediation projects, including detailed design, procurement options, contracts and quality management.

INFO-IMP2	Key Information Sources: Implementation of the Remediation Strategy – Implementation, Verification and Monitoring		
INFO-IMP2a	**EA (In prep)**		**Verification of Remediation of Contaminated Soils and Water**
	o	**C**	This provides a framework for the verification of remediation of soil and groundwater contamination that can be applied to both simple and complex situations. It introduces the use of statistical tools as a means of adding confidence that the remedial criteria have been achieved.

INFO-SC1	Key Information Sources: Site Characterisation – General	
INFO-SC1a	DoE, 1994 ● A	**Guidance on Preliminary Site Inspection of Contaminated Land, CLR2** Guidance on what indicators of potential contamination to look for when carrying out site reconnaissance. Indicators include abiotic features (such as debris and topographic anomalies) as well as biotic indicators (e.g., signs of vegetation damage). Also includes a checklist and an assessment form that can be used by site personnel.
INFO-SC1b	EA, 2000 ● C	**Technical Aspects of Site Investigation in Relation to Land Contamination, 2 volumes, P5-065/TR** This document provides guidance to those involved in the site characterisation process on the technical aspects of site investigation. It deals with the subject from a project manager's standpoint, rather than that of a 'hands-on' specialist.
INFO-SC1c	BSI, 2001 ● J	**Investigation of Potentially Contaminated Sites, Code of Practice, BS:10175** This document contains technical advice on the design and implementation of site characterisation (including intrusive site investigation) activities for contaminated land. It focuses on the selection and use of different field sampling and monitoring techniques, collection, handling and transport of samples, and reporting of field observations and related data.
INFO-SC1d	CIRIA, 2003 ● F	**Best Practice Guidance for Site Characterisation, Produced by SAFEGROUNDS Learning Network (www.safegrounds.com)** This document deals with the characterisation of contaminated and potentially contaminated land on nuclear-licensed sites and defence sites, and covers both radioactive and non-radioactive contamination. The guidance focuses on those parts of a site investigation that are specific to these industrial sectors and that differs from site investigation on most other contaminated sites.

INFO-SC2	Key Information Sources: Site Characterisation – Sampling Design	
INFO-SC2a	**CIRIA, 1993** ● **F**	**The Measurement of Methane and Other Gases from the Ground, R131** Considers the various techniques available for measuring methane and other ground gases, and their associated capabilities and limitations.
INFO-SC2b	**DoE, 1994** ● **A**	**Sampling Strategies for Contaminated Land** Contains guidance on the development of effective sampling strategies using statistical techniques to determine optimal sampling patterns and densities. Provides the basis for more recent advice (INFO-SC2d) on the development of appropriate sampling strategies for contaminated soils.
INFO-SC2c	**CIRIA, 1995** ● **F**	**Methane Investigation Strategies, R150** Contains technical advice on the development of appropriate sampling strategies including staging investigations, number and position of sampling locations, design and construction of monitoring wells, duration of monitoring programmes, etc.
INFO-SC2d	**EA, 2001** ● **C**	**Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination** Summarises the key design issues to be considered when developing 'fit for purpose' soil-sampling strategies in land contamination applications. Contains procedures that can be used to guide the design process, and to check the technical validity of proposed or completed design work. The document also contains advice on determining an appropriate number of samples during detailed investigations, and a series of case studies that illustrate the development of sampling strategies in typical applications.
INFO-SC2e	**EA, 2002** ● **C**	**Review of Ecotoxicological and Biological Test Methods for the Assessment of Contaminated Land, R&D Technical Report, P300** The report reviews national and international literature for biological and ecotoxicological tests that can be used to assess soil quality for ecological risk assessment purposes. The report contains a list of suitable tests based on applicability to ecological risk assessment applications, standardisation of test methods, ease of use and cost. The tests use a range of organisms, including micro-organisms, soil invertebrates and plants, and are relevant to the full spectrum of biological organisation from molecular and biochemical levels up to groups of individual organisms.

INFO-SC3	Key Information Sources: Site Characterisation – Field and Laboratory Analysis		
INFO-SC3a	EA, 2002		**In-vitro Methods for the Measurement of the Oral Bioaccessibility of Selected Metals and Metalloids in Soils: A Critical Review, R&D Technical Report/TR02**
	●	C	This report presents a review of in-vitro tests that are currently used to evaluate the ingestion bioaccessibility of selected metals and metalloids in contaminated soils. The report includes a brief outline of the methodologies and a critical commentary on their robustness and validity for measuring the bioaccessibility of substances via the human and animal oral pathway.
INFO-SC3b	EA, 2003		**The Agency's Monitoring Certification Scheme: MCERTS Performance Standard for Laboratories Undertaking the Chemical Testing of Soil (Version 2)**
	●	C	MCERTS provides assurance to all stakeholders (e.g., laboratories, Local Authorities, consultants, non-governmental organisations) on the reliability of data from the chemical testing of soils. Where results are to be submitted to the Agency for regulatory purposes, the Agency requires a laboratory to be accredited to the European and International Standard, BS EN ISO/IEC 17025:2000. The MCERTS performance standard builds on this by providing an application or BS EN ISO/IEC 17025:2000 specifically for the chemical testing of soil.
INFO-SC3c	EA, 2000		**Non-intrusive Investigation Techniques for Groundwater Pollution Studies, R&D Technical Report P403**
	●	C	This report describes non-intrusive investigation (including geophysical) techniques for groundwater pollution investigations. Technical summary sheets have been produced for a number of individual techniques.
INFO-SC3d	EA (In prep)		**Techniques for the Characterisation of Land Contamination**
	o	C	This report provides a review of innovative and emerging and proven techniques that may be used to characterise soil and water contamination. Tools and techniques that can be used to provide a rapid assessment of contamination can allow quicker decision making, which improves the efficiency of contaminated land management. This document provides users with a practical selection matrix that will assist in selecting suitable techniques.

III

INFO-PM1	Key Information Sources: Project Management – Guidance Specific to a Particular Industrial or Commercial Sector	
INFO-PM1a	**ICRCL (various dates)** ● **K**	**ICRCL Guidance Notes:** • The Development and After-use of Landfill Sites, 17/78, Eighth Edition, 1990; • The Redevelopment of Gasworks Sites, 18/79, Fifth Edition, 1986; • The Redevelopment of Sewage Works and Farms, 23/79, Second Edition 1983; • The Redevelopment of Scrap Yards and Similar Sites, 42/80, Second Edition, 1983; • The Fire Hazards of Contaminated Land, 61/84, Second Edition, 1986; • Asbestos on Contaminated Sites, 64/85, Second Edition, 1990; • The Restoration and Aftercare of Metalliferous mining sites for pasture and grazing, 70/90, 1990. Guidance notes produced by the former Interdepartmental Committee for the Redevelopment of Contaminated Land to advise local authorities, developers and others involved in redevelopment projects about the potential hazards in redeveloping former industrial sites. Although now rather dated, these documents contain useful information on previous industrial practices and key features of different site types.
INFO-PM1b	**IoP, 1998** ● **L**	**Guidelines for Investigation and Remediation of Petroleum Retail Sites** Sets out good practice technical guidance on the assessment and management of contamination that may be associated with petroleum retail premises (e.g., petrol stations).
INFO-PM1c	**EA & NHBC 2000** ● **C**	**Guidance for the Safe Development of Housing on Land Affected by Contamination, R&D Publication 66** Aimed specifically at housebuilders and their advisors. It sets out good practice principles for the assessment and remediation of contaminated land intended for housing development and includes summary information on the hazardous properties of a range of commonly encountered substances.
INFO-PM1d	**BRE, 2001** ● **B**	**Protective Measures for Housing on Gas – Contaminated Land, R&D Technical Report P336** A practical guide to current good practice for the design and construction of passive soil gas protective measures for new and existing residential development. (Cont.)

INFO-PM1	Key Information Sources: Project Management – Guidance Specific to a Particular Industrial or Commercial Sector (Cont.)		
INFO-PM1e	**CIRIA, 2002**		**Brownfields: Managing the Development of previously Developed Land – a Client's Guide**
	●	**F**	Guidance intended mainly for clients who may be new to the process of redeveloping previously used land. It covers the key issues and will enable clients to take a view on where and how advisory support may be obtained.
INFO-PM1f	**CIRIA, 2002**		**Good Practice Guidance for the Management of Contaminated Land on Nuclear and Defence Sites, produced by SAFEGROUNDS Learning Network (www.safegrounds.com)**
	●	**F**	The SAFEGROUNDS Learning Network has published guidance that identifies five key principles for the management of contaminated land on nuclear and defence sites. These principles are: (i) protection of people and the environment, (ii) stakeholder involvement, (iii) identifying the preferred land management option, (iv) immediate action and (v) record keeping. This guidance expands on these key principles and indicates how they can be put into practice within a structured approach to managing land affected by contamination.
INFO-PM1g	**WDA, 2004**		**WDA Manual on the Management of Land Contamination**
	●	**M**	Produced as guidance to Welsh local authorities, project managers and developers involved in WDA-funded remediation projects. This document sets out a practical guide to good practice on the assessment and remediation of contaminated sites.

INFO-PM2	Key Information Sources : Project Management – Health and Safety and Quality Management	
INFO-PM2a	**HSE, 1991**	**Protection of Workers and the General Public during the Development of Contaminated Land**
	● **P**	Sets out the key principles to take into account when designing and implementing work on contaminated sites to ensure proper protection of the health and safety of employees and others who may be affected by such work.
INFO-PM2b	**CIRIA, 1996**	**A Guide for Safe Working on Contaminated Sites, R132**
	● **F**	Similar to the HSE document described above and includes checklists to help in the preparation of health and safety risk assessments, development of safe working procedures, provision of protective clothing and equipment, etc.
INFO-PM2c	**DoE, 1997**	**A Quality Approach for Contaminated Land Consultancy, CLR 12**
	● **A**	This report focuses on the procurement and delivery of consultancy services in the area of contaminated land and considers the steps that consultancies should take to assure the quality of the advice they provide. Although the report is directed at the consultancy industry, it is also relevant to clients who need to engage the services of environmental consultants.

INFO-PM3	Key Information Sources : Project Management – Communication	
INFO-PM3a	**SNIFFER/EA, 1999** ● **Q**	**Communicating Understanding of Contaminated Land Risks, SR97(11)F** Contains practical advice to regulators and practitioners on how to effectively communicate risk-based information on land contamination to non-specialist groups. Covers the basic principles of effective communication and advises on different methods, including preparation and distribution of written material, oral presentations, public meetings, etc.
INFO-PM3b	**CIRIA, 2002** ● **F**	**Community Stakeholder Involvement, produced by SAFEGROUNDS Learning Network (www.safegrounds.com)** This report was prepared within the SAFEGROUNDS Learning Network and supplements the good practice guidance for the management of contaminated land on nuclear and defence sites. It contains additional information on good practice in stakeholder involvement in decisions that relate to the management of contaminated land on nuclear and defence sites, and in the implementation of chosen land management options. Its focus is the community local to the site and it does not deal in any detail with involvement of stakeholders such as regulators, government departments and those from the site owner's and/or operator's own organisation.
INFO-PM3c	**EA, 2004** ● **C**	**Participatory Risk Assessment: Involving Lay Audiences in Decisions on Environmental Risk. E2-043** This report aims to inform the Agency's developing approach to the practical involvement of non-specialist stakeholders in environmental risk assessment.

Information Map – Abbreviations And Document Source Details

Letter Code		Issuing body
A	DoE	Department of the Environment
B	BRE	Building Research Establishment
C	EA	Environment Agency
D	Defra	Department for Environment, Food and Rural Affairs
E	ASTM	American Society for Testing and Materials
F	CIRIA	Construction Industry Research and Information Association
G	DETR	Department of Environment, Transport and the Regions
H	ICE	Institute of Civil Engineers
J	BSI	British Standards Institution
K	ICRCL	Interdepartmental Committee for the Redevelopment of Contaminated Land
L	IoP	Institute of Petroleum (now known as The Energy Institute)
M	WDA	Welsh Development Agency
N	TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
P	HSE	Health and Safety Executive
Q	SNIFFER / SEPA	Scottish and Northern Ireland Forum for Environmental Research /Scottish Environment Protection Agency
R	CL:AIRE	Contaminated Land: Applications in Real Environments
S	IWM	Institute of Waste Management (now known as the Chartered Institute of Waste Management – CIWM)
T	ODPM	Office of the Deputy Prime Minister

Contact Details for Copies of Documents

Issuing Body		Postal Address	Web-site
A	DoE	Defra Publications, c/o IFORCE Ltd, Imber Court Business Park, Orchard Lane, East Molesey, Surrey, KT8 0BZ	www.defra.gov.uk
B	BRE	BRE Publications, CRC Ltd, 151 Rosebery Avenue, London, EC1R 4GB	www.bre.co.uk
C	EA	Environment Agency National Customer Contact Centre (Tel. 0870 506 506), Templeborough Office, Rotherham S60 1BY (email: enquiries@environment-agency.gov.uk)	www.environment-agency.gov.uk
D	Defra	Contaminated Land Branch, Defra, ELEQ Division, Zone 4/D11, Ashdown House, 123 Victoria Street, London, SW1E 6DE	www.defra.gov.uk
E	ASTM	American Technical Publishers Ltd, 27–29 Knowl Place, Wilbury Way, Hitchin, Herts, SG4 0SX	www.americtech.co.uk
F	CIRIA	Classic House, 174–180 Old Street, London, EC1V 9BP	www.ciria.co.uk
G	DETR	Stationery Office, PO Box 276, London, SW8 5DT	www.defra.gov.uk
H	ICE	Thomas Telford, Thomas Telford House, 1 Heron Quay, London, E14 4JD	www.t-telford.co.uk
J	BSI	BSI Customer Services, 389 Chiswick High Road, London, W4 4AL	www.bsi-global.com
K	ICRCL	Defra Publications, c/o IFORCE Ltd, Imber Court Business Park, Orchard Lane, East Molesey, Surrey, KT8 0BZ	www.defra.gov.uk
L	IoP	61 New Cavendish Street, London, W1G 7AR	www.petroleum.co.uk
M	WDA	QED, Treforest Industrial Estate, Treforest, Pontypridd, CF37 5YR	www.wda.co.uk
N	TPHCWG	Amherst Scientific Publishers, 150 Fearing Street, Amherst, MA 01002, USA	www.aehs.com
P	HSE	PO Box 1999, Sudbury, Suffolk, CO10 2WA	www.hse.gov.uk
Q	SNIFFER/SEPA	Scottish Environment Protection Agency, Head Office, Erskine Court, The Castle Business Park, Stirling, FK9 4TR	www.sniffer.org.uk
R	CL:AIRE	5th Floor, 2 Queen Anne's Gate Buildings, Dartmouth Street, London, SW1H 9BP	www.claire.co.uk
S	CIWM	9 Saxon Court, St Peter's Gardens, Marefair, Northampton, NN1 1SX	www.ciwm.co.uk
T	ODPM	26 Whitehall, London, SW1A 2WH	www.odpm.gov.uk

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