Chartered Institute of Environmental Health

Guidance for the Safe Development of Housing on Land Affected by Contamination

R&D Publication 66: 2008 Volume 1

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Foreword

The safe development of housing on Brownfield land is a fundamental element in the delivery of sustainable development. The Barker review commented *"housing is a basic human need – fundamental to economic and social well being"*. Accordingly house building rates need to rise substantially to avoid increased homelessness and social division – but this should not be at the expense of losing our precious green open spaces.

Paramount to the sustainability of such development is the management of environmental risks both during construction and also to ensure the subsequent safe occupation by the new residents. This Guidance has been written to support and supplement the substantial body of existing advice in this field. Our aim has been to ensure that it is consistent with current best practice, it aligns with the Model Procedures and that it provides pragmatic and accessible advice which is equally useful and relevant to developers, regulators and their specialist advisors.

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Publication and acknowledgements

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The authors of this report are employed by Buro Happold and Enviros. The work reported here was carried out under a contract with the NHBC dated 30th January 2007. Any views expressed are not necessarily those of the NHBC, the Environment Agency or the CIEH. The publication is designed to provide accurate and authoritative information on the safe development of housing on land affected by contamination. It is made available on the understanding that neither the authors not the publishing organisations are engaged in providing a specific professional service. Whilst every effort has been made to ensure the accuracy and completeness of the document, no warranty or fitness is provided or implied. The authors and the officers of the publishing organisations accept no responsibility for any loss or damage arising from the interpretation or use of the information, or reliance upon views contained herein.

This report has been developed from R&D66 published in 2000. That document was produced under the Environment Agency R&D Project P5-24 by CES and was jointly funded by the Environment Agency and the National House-Building Council (NHBC). This current report up-dates R&D66 (2000) by reference to numerous publications but most importantly to the Environment Agency Model procedures (CLR11).

The preparation of the report which was sponsored by the NHBC was carried out by a consortium drawn from Buro Happold and Enviros overseen by a steering group consisting of George Fordyce (NHBC), Trevor Howard (Environment Agency) and Bill Baker (Chartered Institute of Environmental Health). The main authors were Hugh Mallett (Buro Happold) and Louise Beale (Enviros) who gratefully acknowledge the advice and assistance provided by the Steering Group and also by their respective colleagues, most notably Maddy Bardsley, Heidi Hutchings and Tim Rolfe (Enviros) and Simon Pilkington and Louise Taffel Andureau (Buro Happold).

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Executive summary

This Guidance has been prepared on behalf of the NHBC (National House-Building Council), the Environment Agency and the Chartered Institute of Environmental Health (CIEH). It updates earlier guidance (R&D66 – published in 2000) on the redevelopment of land affected by contamination. The guidance, whilst written to be relevant to housing development on such sites, is also generally applicable to other forms of development, to existing developments and to undeveloped land, where such sites are on land affected by contamination.

In the period since publication of R&D66 in 2000, a substantial body of technical guidance has been produced by the Environment Agency and others, including most importantly the Environment Agency Model Procedures (CLR11). These Model Procedures now form a framework within which the assessment of all sites of land affected by contamination should be carried out. This Guidance has therefore been prepared to accord with the Model Procedures, but has been written and published in a manner designed to enable the practical application of good practice within this framework by all of the relevant parties.

The Government's repeated commitment to the redevelopment of land affected by contamination (for both housing and other developments) emphasises the continued need for the adoption of the good practice procedures described here. Such good practice satisfies the requirements of guidance relevant to development regulated through the planning regime. In addition, development which complies with this good practice guidance will "as a minimum" ensure that the land is not capable of "determination" as Contaminated Land under Part 2A of the Environmental Protection Act.

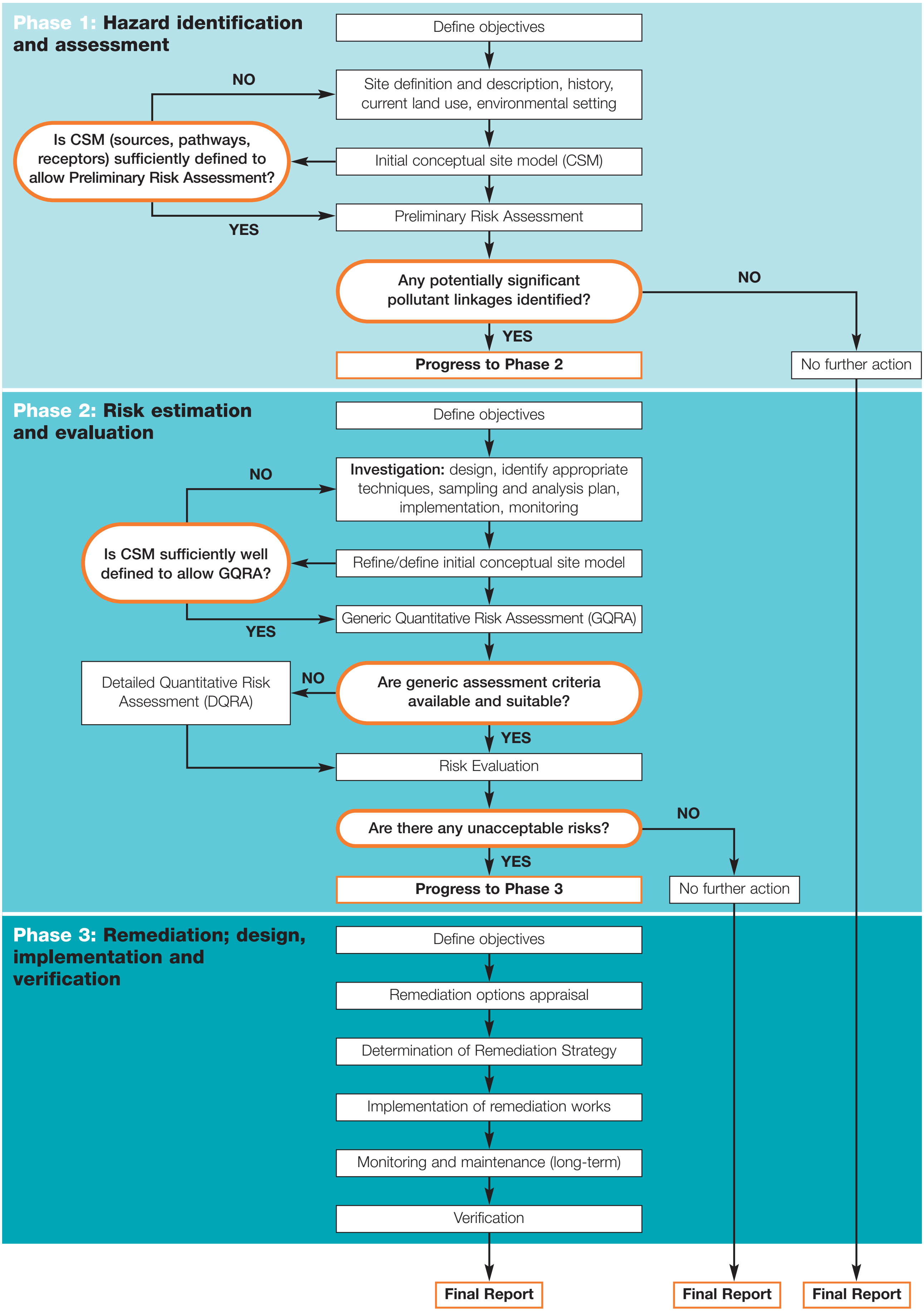
This Guidance describes in some detail the structured series of activities involved in the phased process of the management of land affected by contamination [Chart A].

- **Phase 1** describes the process and activities involved in hazard identification and assessment;
- **Phase 2** describes the process and activities involved in risk estimation and evaluation; and
- **Phase 3** describes the process and activities involved in remediation; design, implementation and verification.

The text in the Guidance is supported by a series of Appendices and technical Annexes which are presented in Volume 2.

KEY WORDS
Land affected by contamination; contaminated land; Planning Policy Statement 23; Part 2A Environmental Protection Act; housing development; site investigation, risk assessment; risk management; remediation, verification.

Chart A The phased process of the management of land affected by contamination



Introduction

General

This report has been prepared on behalf of the National House-Building Council (NHBC), who funded the work, the Environment Agency and the Chartered Institute of Environmental Health (CIEH). It updates the first edition of R&D66 published in 2000 (Environment Agency/NHBC 2000a), by reference to a substantial body of new regulation, guidance and advice. In particular, this update has been carried out to ensure consistency with the Model Procedures [CLR11] (Defra and Environment Agency 2004a). The guidance is particularly focussed on the development of housing on land affected by contamination. However, the advice is generally applicable to other forms of development and to existing developments.

Content and structure

The contents and structure of this report have been guided by R&D66 (Environment Agency/NHBC 2000a) and by Model Procedures (Defra and Environment Agency 2004a). This introduction sets out the basis of the technical guidance which follows. The principles of the identification and assessment of land contamination are briefly described. These technical/policy issues are then set into the context of housing policy. The main technical guidance of the report is presented in the three chapters of Volume 1, whose titles reflect the three phases of the process of managing land contamination. This text is supported by a series of Appendices and technical Annexes in Volume 2. A Glossary of technical terms and acronyms is presented at Appendix 1 and a listing of organisations involved in matters related to and affected by contamination at Appendix 2.

The policy, legislative and regulatory framework within which this guidance operates is complex. It is briefly described below (pages 11 to 16), with some text describing how the regime operates in Northern Ireland, Wales and Scotland given in Appendix 3.

The structured procedure for managing the potential risks associated with the development of housing on land affected by contamination is illustrated in a flow chart (Chart A). The text in the report follows this logical sequence. Phase 1 describes the tasks necessary to develop an initial conceptual site model. Phase 2 sets out the processes and techniques necessary to confirm or deny the validity of the potential pollutant linkages in this model. Various methods or tools are then described which aid in the assessment of the level of risk particular to each site. Phase 3 describes the process of the appraisal and selection of remediation techniques, its implementation and verification. Each of those Phases of work is detailed by its own flow chart (Charts 1, 2 and 3). This process is also illustrated by a 'case study' in Volume 2.

Table 0.1 **Terminology of the phases in the management of land contamination**

Terminology used in R&D66: 2008	Terminology used in Model Procedures (CLR11)
Phase 1: Hazard identification and assessment [Chart 1]	Risk Assessment (Preliminary) [Figure 2A]
Phase 2: Risk estimation and evaluation [Chart 2]	Risk Assessment (GQRA and DQRA) [Figures 2B and 2C]
Phase 3: Remediation; design, implementation and verification [Chart 3]	Options Appraisal and Implementation [Figures 3A, 3B, 3C and 4A, 4B, 4C]

Readership

This report is relevant to all of the various parties involved in the development of land affected by contamination. Particular attention is given to those involved in housing development, but the advice is also relevant to parties concerned with existing development on land affected by contamination and/or concerned with other types of development.

The parties who will find this report helpful are:

- housebuilders;
- developers;
- local authority and Environment Agency regulators;
- consultants who advise all of the above; and
- other professionals who advise landowners, developers etc. (such as chartered surveyors, insurers, funders etc.).

Objectives

The objectives of this guidance are:

1. To provide concise, accessible advice which is useful, practical and readily capable of implementation by all parties;
2. To describe both the process and examples of good practice in the risk based approach to the assessment of land affected by contamination (but also pitfalls to avoid);
3. To facilitate safe development by the production of consistent procedures, the improvement of data acquisition, interpretation and presentation;
4. To outline the roles and responsibilities of the various parties (e.g. the local authority regulator, the Environment Agency etc.); and
5. To encourage early liaison and a co-operative partnership approach between developers, advisors and regulators.

Consistent application of the principles set out in this report will assist in:

- The provision of confidence to all stakeholders with an interest in the development of housing on land affected by contamination;
- Ensuring that the decision making process is robust, open, transparent, provides traceability and properly reflects site specific variability; and
- The reduction of financial risk and residual liabilities.

Background

Pollutant linkages

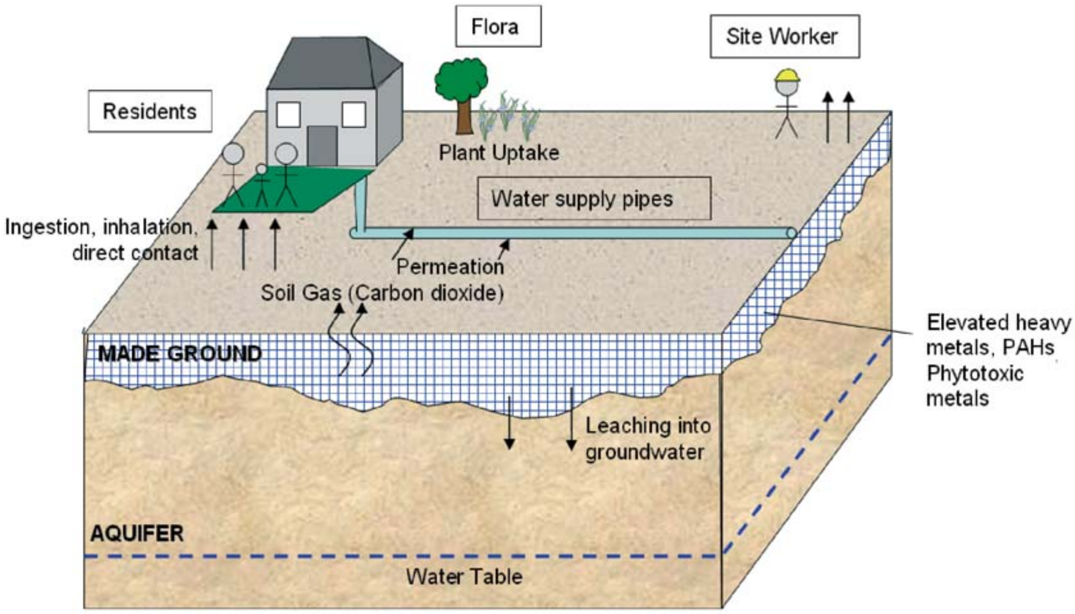
Government policy in relation to land affected by historic contamination is founded on a 'suitable for use' approach (Defra 2006a). This approach informs consideration of sites on land affected by contamination under each of the three main drivers for assessment and remediation, namely:

1. Voluntary action;
2. Development under the planning regime; and
3. Regulatory action to mitigate unacceptable risks, for example, under Part 2A of the Environmental Protection Act 1990.

In order for a risk to be realised related to land affected by contamination, a 'pollutant linkage' must exist. A pollutant linkage requires the presence of:

- a source of contamination;
- a receptor capable of being harmed; and
- a pathway capable of exposing a receptor to the contaminant.

A 'source' of contamination can be defined as a harmful or toxic substance present in the ground (as a solid, liquid or gas/vapour). A 'receptor' can be a person, an environmental subject (groundwater, surface water, flora or fauna) or a building/structure. The exposure pathway can be direct (e.g. skin contact with contaminated soils) or indirect (e.g. movement of a contaminant source through air, as contaminated dust, or via water) eventually to impact the receptor. An example of possible pollutant linkages in a simplified "Conceptual Model" of a site is illustrated below. By consideration of the sources, pathways and receptors in each pollutant linkage, an assessment can be made of the significance and degree of risk.



The presence of contamination

Contamination may be present at a site (in the ground and/or in the underlying groundwater) as a result of a historic or current industrial use. Typically such contamination is present because of leaks, spills or disposal of residue, wastes and excess raw materials. Contamination may also be present due to:

- the purposeful application of chemicals (e.g. the spraying of herbicide/pesticide);
- migration from adjacent land; or
- naturally occurring processes (e.g. elevated concentrations of particular heavy metals associated with specific geological strata).

The extent of contamination in the UK has not been well defined but it has been estimated that there could be up to 200,000 hectares of land affected by contamination in the UK (DETR/ Urban Task Force 1999a) and the Environment Agency estimated that the number of 'problem sites' (i.e. those that may need regulatory intervention) could range from 5,000 to 20,000 (Environment Agency 2002a).

In the context of housing development, government policy encourages the beneficial reuse of brownfield sites having set a target of 60% of new homes being built on such sites. Data from the NHBC (personal communication) showed that between April 2006 and April 2007 just over 11,400 sites were registered with the NHBC that year (down from 12,500 in 2005) and that in total about 40% of all plots were on land that was affected by contamination. These figures could be slightly misleading as a very high proportion (70%) of sites are small (<10 plots) and of these small sites only 30% were on land affected by contamination. For the larger sites (i.e. those with over 50 plots) over 80% were constructed on land affected by contamination.

Housing policy

The Government has acknowledged that there are substantial challenges to be faced in the UK with regard to home provision, namely:

- there is a significant gap between the supply of and demand for new homes;
- from 1970 to 2000 the level of new house building fell by 50% (to rates of around 175,000 per annum in 2000) whilst the number of households increased by 30%;
- the latest forecasts indicate that the number of households in England will grow by some 223,000 per annum of which 70% are single person households; and
- the Government has set ambitious targets to reduce the number of people in temporary accommodation, Bed & Breakfast accommodation, and sleeping rough.

In order to understand the issues better, the Government commissioned a review of housing supply (Barker 2003a and 2004a). This review of housing supply clearly identified that the housing market had not responded sufficiently to meet the demand for new homes. At the time of the report, Government plans for new homes totalled 150,000 per annum. The Government response to the Barker report (ODPM 2005a) signalled a commitment to build more homes for future generations, in particular to increase the rate of new housing build to 200,000 per annum. More recent policy statements have indicated the target will be raised with 2 million new homes to be built by 2016 and 3 million by 2020 (Y Cooper – Ministerial Statement, Hansard 23 July 2007).

In addition to this statistical information, the Barker report also identified some important social aspects related to this lack of provision. In some key phrases, the report noted:

> *"Housing is a basic human need which is fundamental to our economic and social well being."* and *"For many, housing is becoming less affordable."*

The report recognised this fundamental aspect of housing by noting that *"homes are more than shelter"* for people, because having a home will place people as a part of a community. It will provide access to the wide variety of services that are the basis of our social fabric (healthcare, schools, social services etc.). Homes are also the most significant element of a person's/family's financial stability.

One of the conclusions of the review (Barker 2003a) with respect to the rates of housebuilding was *"continuation at current rates is not realistic unless homelessness and social division are accepted"*. Barker made a number of recommendations with respect to housing policy, including that more land should be allocated for development. It was recognised that such a policy would have environmental impacts. However, it was also recognised that these impacts could be reduced by ensuring that land is used efficiently, that *"the most valuable undeveloped land is preserved"* and that *"land which society values least is used"*. The Government's response to these reports has recognised and accepted the basis of these recommendations. Recent policy statements have again signalled the importance the Government places upon the issue of housing: *"putting affordable housing within the reach not just of the few but of the many is vital both to meeting individual aspirations and a better future for our country"* (G. Brown July 2007).

The Government's special advisor on brownfield land, English Partnerships, recognises that much remains to be done in the sustainable reuse of brownfield sites, but was encouraged that in 2005, 74% of new housing was built on such land. In its guide to practitioners (English Partnerships 2006a) the importance of the complex inter-relationships necessary to realise these policy aspirations is stressed. *"Unlocking brownfield land successfully is about vision, leadership, professional skills and using the latest technologies. Creating sustainable environments should be at the forefront in brownfield projects, with land being reused to provide housing, employment and recreation - - -". " - - - Land reuse though is not an end in itself; it is also about local people being engaged in the development process and helping to shape the future use of the areas in which they live, work and spend their leisure time."*

In its response to English Partnerships work in developing a National Brownfield Strategy, the Government acknowledged that the re-use of brownfield land lies at the heart of a wide range of its policies for the revival of our towns and cities and achieving more sustainable patterns of development (CLG 2008a).

The implications for land affected by contamination are clear. The beneficial reuse of brownfield sites for housing can meet these policy aspirations. However, what is also paramount is that any such development must be carried out in a way which is safe for the residents of such sites, safe for their neighbours and without risks being realised to the environment.

Policy, regulation and guidance

European Directives

Soil Framework Directive [Proposed]
The proposal to establish a framework for the protection of soil was first published in September 2006 (EU 2006a). The document recognises that many countries already have in place some provision for soil protection. However because there is no EU legislation on soil protection, the proposal aims to establish a common strategy for the protection and sustainable use of soil. The proposed strategy is to; integrate issues regarding soil into other policies; preserve soil function; prevent threats to soil and to mitigate impacts. The draft Directive was not approved by EU member States in 2007 and at the time of writing this report, the European Commission was considering the future of the Soil Framework Directive.

Water Framework Directive [Directive 92/43/EEC]
The Water Framework Directive (EU 2000a) established a framework for the protection of inland surface waters, coastal waters and groundwater that, amongst other matters; prevents further deterioration, protects and enhances the status of aquatic ecosystems and ensures the progressive reduction of and prevention of future groundwater pollution. The Directive was transposed into UK law in 2003 and is being implemented to an agreed timetable.

Waste Framework Directive [Directive 2006/12/EEC]
The Waste Framework Directive (EU 2006b) provides a definition of waste that informs the Environment Agency's regulatory position (Ref Environment Agency 2006d). [See also Annex 7 of this report]. The Directive also lists different types of waste in the European Waste Catalogue (EWC). The excavation, treatment and re-use of contaminated soils (and groundwaters) on brownfield sites may involve materials which fall within this definition of 'waste' and therefore fall into the waste regulatory regime and require description under the EWC.

Landfill Directive [1999/31/EEC – supplemented by Council Decision 2003/33/EC]
The objective of the Landfill Directive (EU 1999a) was to prevent or reduce as much as possible the environmental impacts of landfills and landfilling operations. Wastes consigned to landfill must now comply with the criteria and procedures defined by the EU. Implementation of this Directive has had a significant impact upon the development of land affected by contamination, as costs for disposal to landfill have increased substantially and the number of landfills capable of accepting these wastes has reduced.

National policy

The Government's 'suitable for use' policy with respect to land affected by historic contamination:

- ensures land is suitable for its current use;
- ensures land is made suitable for planned future use(s); and
- limits the scope of remediation to that necessary to mitigate unacceptable risks.

The adoption of this policy will also ensure appropriate reconciliation of the various environmental, social and economic needs with respect to land affected by contamination.

English Partnerships guidance is aimed at assisting the decision making process at each phase of brownfield redevelopment (English Partnerships 2006a). It acknowledges that the redevelopment of brownfield land tends to be more complex and may expose developers to more risk than on greenfield sites.

Strategic planning

Spatial Strategies

Spatial Strategies [Regional Spatial Strategies in England (various authors and dates), the Wales Spatial Plan (Welsh Assembly Government 2004a), National Planning Framework for Scotland (Scottish Executive 2004a); N. Ireland – Shaping our future 2025 (Department for Regional Development Northern Ireland 2001a)] aim to make the planning system play a more strategic and proactive role in sustainable development. Land affected by contamination is a material planning consideration in these strategies and soils are identified as one of the environmental considerations for sustainable development to be considered in such strategies. The Environment Agency is recommending that all such plans and strategies draw appropriate attention to the potential for contamination and that all developments incorporate proper risk assessment, remediation and long-term management. In some key messages the Environment Agency stresses the importance of the Water Framework Directive, a holistic ('area based') approach to remediation which encourages sustainable remediation, enables appropriate development and which is appropriately validated.

Brownfield Action Plans

The Sustainable Communities Plan (SCP), published by the ODPM in February 2003 (ODPM 2005b), refers to the proposed National Brownfield Strategy (English Partnerships 2003a) with the specific aim of bringing a significant proportion of previously used land back into beneficial use. Accordingly, the Government called upon the RDAs to produce Brownfield Land Action Plans. Such Plans will be produced in co-operation with local authorities and other relevant agencies and statutory bodies and will fit closely with the Regional Economic Strategies and Regional Housing Strategies.

Legislation, regulation and guidance

There are two primary legislative/regulatory drivers which require the assessment of land affected by contamination prior to the re-development of a site:

1. The Town and Country Planning Act (1990) (OPSI 1990a) and related Planning Guidance;
2. Building Regulations (2000) (OPSI 2000a).

The particular Regulations and Guidance associated with these primary instruments vary between England, Wales, Scotland and Northern Ireland (see Appendix 3). Other regulatory regimes relevant to the development of land affected by contamination (e.g. regarding environmental assessment, controlled waters and waste) are also briefly described below. In addition to these Regulations and Guidance which apply solely with respect to development, Part 2A [Part 3 in Northern Ireland] of The Environmental Protection Act 1990 (as inserted by Section 57 of the Environment Act 1995) and associated Statutory Guidance (Defra 2006a) which apply principally with respect to historic contamination, are also significant in the development context.

The planning regime

In circumstances where sites are subject to redevelopment, the developer assumes responsibility for the costs of any remediation necessary to ensure safe development. Proposals for development are subject to scrutiny via the planning system. Developers must demonstrate to the satisfaction of the local authority that they have addressed all matters of material planning consideration (including contamination). In circumstances where land affected by contamination is to be redeveloped, advice provided under the planning regime is relevant [PPS 23 in England (ODPM 2004a) and PAN33 in Scotland (Scottish Executive 2000a) – see Appendix 3]. These documents provide advice on the implications of contamination for the planning system and advise local authorities about the determination of planning applications when the site is, or may be, contaminated. These guidance documents include clear statements that consideration of land quality and potential impacts arising from development are a "material planning consideration". A key provision of planning guidance is to ensure that the land is made suitable for its proposed new use. For example, PPS 23 states that local planning authorities must be satisfied that *"the potential for contamination and any risks arising are properly assessed"* [i.e. that the conceptual site model is sufficiently well designed] *"and that the development incorporates any necessary remediation and subsequent management measures to deal with unacceptable risks"*.

On sites where the land is known or suspected to be affected by contamination, developers must provide sufficient information with the planning application to demonstrate the existence (or otherwise) of contamination, its nature, extent, and the risks it may pose as well as evidence that such risks can be mitigated to an acceptably low level. It is recognised that following the phased approach (described in both Model Procedures and R&D66: 2008) does not necessarily mean that a detailed site investigation is required with every planning application. However, applicants are advised that **as a minimum** a desk study (including a walkover survey) should be carried out. This Desk Study will be sufficient only if it is capable of developing a conceptual site model identifying the sources of contamination and the pathways linking them to receptors. In addition, the Desk Study report must identify the means by which the pollutant linkages can be broken.

The expectation should be that on land affected by contamination, developers will have to carry out a phased programme of assessment which will include intrusive investigations. In order to ensure mutual understanding regarding the likelihood and possible extent of contamination and any implications for the proposed development, developers should, wherever practical, carry out pre-application discussions with all interested parties of the local authority (in particular, planning, environmental health, contaminated land officers and Building Control).

If the desk study confirms the potential presence of contamination, then further studies and investigations by the developer must be carried out to assess risks and identify the need for and scope of any remediation. Any remediation must remove unacceptable risk and make the site suitable for its new use. As a minimum, any such remediated and redeveloped sites should not be capable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990. PPS 23 also encourages developers and local authority regulators to utilise the opportunities presented by the development of land affected by contamination to enhance the environment.

Building Regulations

The Building Regulations (OPSI 2000a) aim to make sure that people living in and around buildings can do so without adverse effects upon their health and safety. The Regulations also set minimum requirements for the functioning of the building (e.g. environmental performance, accessibility etc.). The Guidance for meeting the requirements of the Regulations is set out in a series of related publications. Approved Document C (ODPM 2004b) deals with land affected by contamination and it requires that:

- reasonable provisions are made to secure the health and safety of persons in and about the building;
- people and the buildings themselves are safeguarded against contaminants on or in the site which will be occupied by the building and land associated with it; and
- people and the buildings themselves are safeguarded against contaminants on or in groundwater beneath the site which will be occupied by the building and land associated with it.

The Building Regulations require builders/developers to obtain building control approval of new developments. This is achieved by means of an independent check carried out by a building control provider (see below) whose responsibility it is to determine that the Regulations have been complied with.

The Environmental Protection Act and Statutory Guidance

Part 2A of the Environmental Protection Act 1990 and the Statutory Guidance (Defra 2006a, WAG 2006a and Scottish Executive 2006a) describe the contaminated land regime and is primarily aimed at dealing with the legacy of contamination. The main objective of this regime is the provision of a system to identify and remediate sites where, for the current use, contamination is giving rise to unacceptable risks to people or the environment. The government also anticipated that this regime would encourage voluntary remediation by land owners/occupiers. Under this regime, responsibility for dealing with the costs of remediation accord with the polluter pays principle. If the 'polluter' cannot be found, this liability passes to the current landowner (or other parties identified via a series of tests set out in the Statutory Guidance).

Other regulatory regimes
There are a number of other regulatory regimes which do, or can, affect the development of land affected by contamination. A detailed description of all of these legal and regulatory regimes is outside the scope of this document. However, a summary of the main issues related to each is set out in tabular form below, with some additional detail also presented in Appendix 3 where applicable.

Table 0.2 Summary of other relevant regulatory regimes

Issue	Regulation title	Comment
Environmental impact assessment	Town and Country Planning (Environmental Impact Assessment) England and Wales) Regulations 1999 Environmental Impact Assessment (Scotland) Regulations 1999 The Planning Environmental Impact Assessment (Northern Ireland) Regulations 1999	Requires developers of certain categories of project to carry out evaluation of the likely effects their proposals for development may have on the environment. An EIA will also identify the mitigation measures that will be implemented to reduce or remediate adverse impacts.
Flood risk assessment	Planning Policy Guidance Note 25: development and flood risk. PPG 25 (2001) Scottish Planning Policy (SPP 7). Planning and flooding (2004) N Ireland. Planning Policy Statement 15 (PPS 15) Planning and flood risk June 2006	Describes the approach that must be adopted by planners/developers to the assessment of flood risk for new developments. This may be relevant to development on land affected by land contamination where for example remediation solutions may become impaired by flooding.
Controlled waters [Groundwater and surface water bodies]	Water Resources Act 1991	Empowers the Environment Agency to issue a 'Works Notice' requiring remediation of controlled waters where there is pollution or likelihood of pollution.
	Groundwater Regulations 1998	Requires authorisation for the disposal of List I or List II substances under Part 2 of the EPA 1990. Describes procedures for prohibiting or regulating activities on land that pose a threat to groundwater from List I/II substances.
Waste management	Waste Management Licensing Regulations 1994	Describes the regulatory responsibilities of the Environment Agency to issue and maintain registers of waste management licences, exemption certificates, enforcement and licence surrender.
	Environmental Permitting Regulations	The Environmental Permitting regime in force from April 2008 streamlines and combines Waste Management Licensing and Pollution Prevention and Control to create a single approach to permit application, maintenance, surrender and enforcement. www.defra.gov.uk/environment/epp

Financial Regulations
A number of financial incentives have been introduced by the Government in order to incentivise the development of land affected by contamination and other brownfield sites. Contaminated Land Tax Credit Land Remediation Relief (Schedule 22 Finance Act 2001 (OPSI 2001a)) was introduced to provide 150 per cent accelerated tax credit to cover the costs of cleaning up land affected by contamination. This relief is subject to conditions which essentially relate to costs being incurred because of the presence of contamination which would not have been incurred for a comparable greenfield site. This was extended to cover Japanese Knotweed in 2008.

Wastes disposed of at landfill sites are subject to landfill tax. In 2007/8, the rate of landfill tax was £24/tonne and is to increase at £3 per annum until 2010. Contaminated spoil arising from the reclamation of land affected by contamination may be exempt from landfill tax subject to certain conditions, provided the reclamation; involves the reduction or removal of harmful contaminants from the site and facilitates development (or the provision of amenity/agricultural uses). This exemption will be phased out from 2012.

Early consultation with HM Revenue and Customs about either form of tax relief is recommended to ensure eligibility and to allow for processing of applications www.hmrc.gov.uk. The Treasury have recently proposed changes to these Financial Regulations www.hm-treasury.gov.uk. It appears likely that the tax credit scheme will be replaced by 'Derelict Land Relief', the details of which are yet to be finalised, but may be broadly similar to the original scheme. However, it also appears likely that the exemption from landfill tax for development schemes on land affected by contamination is likely to be withdrawn, although details for transitional measures (if any) have not been determined.

Roles and responsibilities

The roles and responsibilities of the various parties involved in the development of land affected by contamination **and the consultants who may advise them** are summarised below.

Table 0.3 Summary of roles and responsibilities

Party	Roles and responsibilities
Owner/ developer	Responsible for implementing site investigations using appropriately qualified persons, sufficient to undertake an appropriate assessment of potential risks. Responsible for demonstrating that potentially unacceptable risks can be successfully mitigated by remediation. Responsible for implementation of remediation works and verification. Particular responsibilities under CDM Regulations.
Local Planning Authority Local	Responsible for determining the appropriateness and acceptability of the developer's site investigation, risk assessment and proposal for remediation. Responsible for control of development, taking into account all material consideration including contamination. Responsible for ensuring that planning conditions are complied with.
Environmental Health [Contaminated Land Officers]	Responsible for carrying out duties of inspection and determination under Part 2A of the Environmental Protection Act 1990. Responsible for the provision of advice to Planning Department colleagues on technical matters related to land affected by contamination to include monitoring of compliance with planning conditions/Section 106 agreements. Responsible for determination of appropriateness and acceptability of the developer's site investigation, risk assessment and proposals for remediation.
Environment Agency	Responsible as the enforcing authority under Part 2A for 'Special Sites'. Responsible for control under the PPC Regulation to prevent future contamination. Responsible for the protection of controlled waters (under the Water Resources Act 1991 and Water Industry Act 1991). During development, responsible as a consultee (currently only on certain planning applications) to advise on pollution of controlled waters and waste management.
Health & Safety Executive	Responsible for the enforcement of health and safety at work (and provide particular advice when working on land affected by contamination. Particular provisions under CDM.
Local Authority Building Control	Responsible for implementation/enforcement of Building Regulations (ODPM 2004b). Consult with Environmental Health where contamination suspected.
National House-Building Council	An 'approved inspector' and able to grant approval under Building Regulations in England and Wales. Provider of the NHBC Warranty which covers both structural defects and land contamination for a period of 10 years. [Warranties similar to the NHBC Warranty are also provided by other insurance providers.]

The technical framework

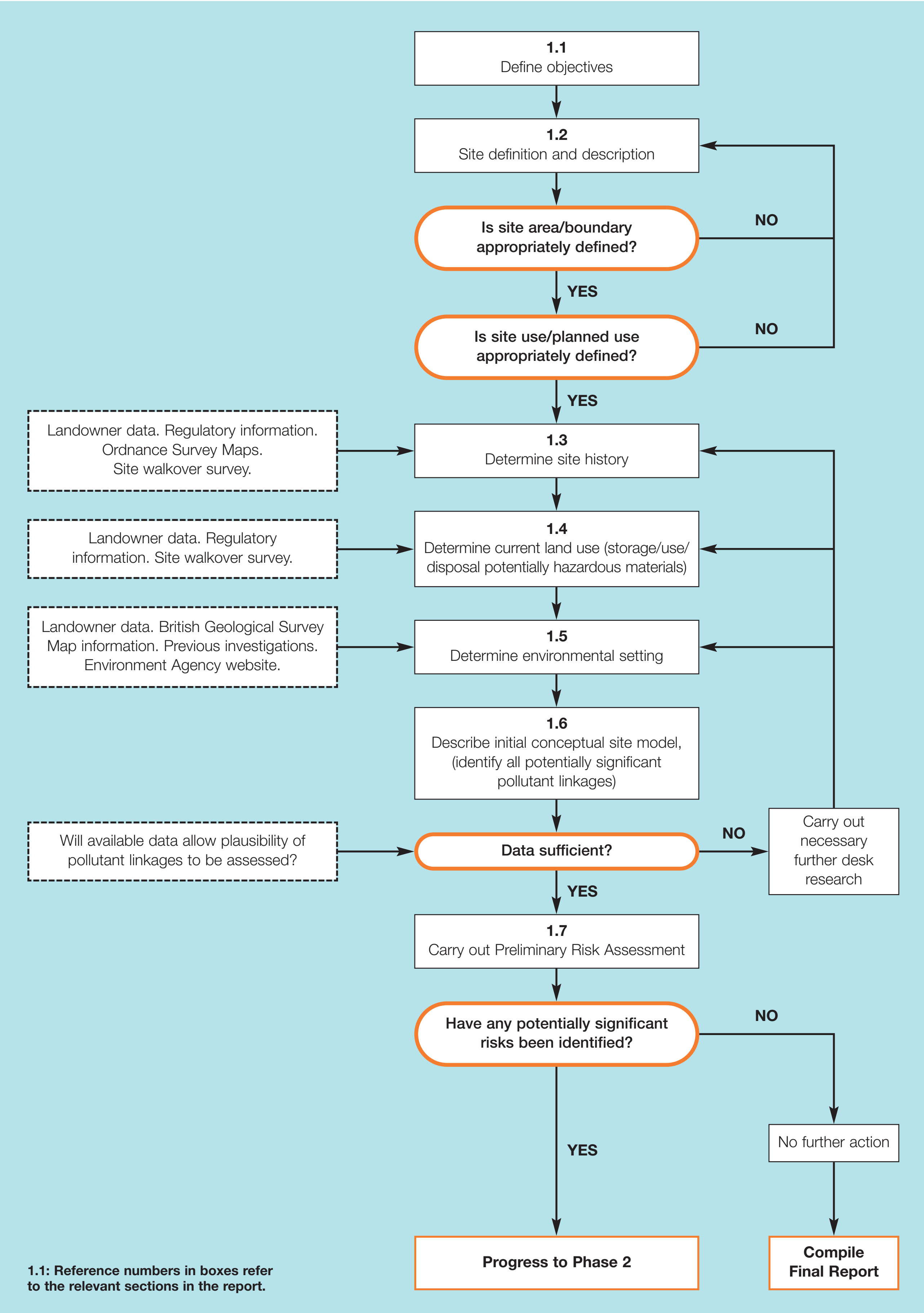
In the UK, the ‘suitable for use’ approach ensures that the management of land affected by contamination is risk based. This risk based approach applies to consideration of such land under both Part 2A of the Environmental Protection Act 1990 and under planning, and is described in the Model Procedures (Defra/Environment Agency 2004a). This document provides a technical framework on which decisions about land affected by contamination are based. This framework assists all stakeholders involved in making management decisions about such land: landowners, developers, regulators and their professional advisors. [The framework in Model Procedures has also informed the structure and content of this document, R&D66: 2008].
It is recommended that all elements of the investigations, assessment and remediation of land affected by contamination are properly referenced to and compliant with, relevant guidance (such as Model Procedures), British Standards (such as BS10175 (BSI 2001a) and BS5930 (BSI 1999a)) and other industry good practice documents referred to throughout this document.

To support this risk based approach, Government Departments, the Environment Agency and others (e.g. CIRIA, CL:AIRE, CIEH, BRE and AGS) have produced a considerable body of technical guidance, information and advice. This documentation is referred to throughout the technical advice in this report (Chapters 1 to 3) and is also listed in the references and bibliography at the end of this Volume 1.

One element of this body of guidance is concerned with ‘guideline values’. These values are concentrations of particular chemical determinands in soils which can be used as generic assessment criteria in the assessment of risk to people. A series of reports presenting these Soil Guideline Values (SGVs) were published by the Environment Agency in 2002/2003 (see Bibliography). Concerns were expressed by a number of bodies about the use/practicality of some of these SGVs in response to which the Government set up an SGV Task Force. As a result of the work of this Task Force, proposals for a way forward were published for public consultation (Defra 2006b). At the time of preparing this report, the results of Defra’s consideration of the consultation responses has not been published. However, the technical guidance presented in Chapters 1 to 3 has been drafted so as not be reliant on any particular threshold values.

In its response to English Partnerships National Brownfield Strategy, the Government signalled its intention to set up a National Brownfield Forum (CLG 2008a). The stated aim of this Forum is to *“bring together Whitehall Departments, the Environment Agency, the Health Protection Agency and industry stakeholders with the aim of promoting a more cohesive and inclusive approach to policy development and to encourage the exchange of best practice and knowledge”*.

Phase 1: Hazard identification and assessment



Phase 1
Hazard identification and assessment

1.1 Objectives

1.1.1 General

The overall aim of the Phase 1 work (often referred to as a "Desk Study") is to identify and assess the potential hazards that could be present on a particular site. It is important to remember that there will always be some site specific factors which, in combination are particular to that site. Every site must therefore be considered unique and thus considered on its own merits. The process of hazard identification and assessment begins with the description of the context of the site and the definition of the risk assessment objectives. It progresses by means of a series of tasks to conclude with a Preliminary Risk Assessment as illustrated in Chart 1 [and by the Case Study, Chart 1A in Volume 2].

The process of hazard identification and assessment thus comprises:

- Definition of objectives [Section 1.1.2];
- Description of the site, in terms of location, extent, boundaries and current appearance [Section 1.2];
- Determination of the history of the site land use [Section 1.3];
- Identification of the current land use, including use/storage of hazardous materials etc. [Section 1.4];
- Description of environmental setting and establishment of site sensitivity [Section 1.5];
- Description of the initial conceptual site model [Section 1.6].

The results of these tasks will allow a Preliminary Risk Assessment to be undertaken [see Section 1.7] which in turn will inform the identification of potentially significant pollutant linkages and determine the need for and scope of any further investigations (desk based or intrusive) in Phase 2.

Remember:
The sequence/timing of these tasks can be critical. For example, the site location and extent must be clearly established and defined before any of the subsequent tasks can be carried out.

1.1.2 Definition of objectives

Both the objectives and the scope of the assessment will vary according to who commissions the work, their reasons for such a commission as well as site specific factors, such as any regulatory involvement/action; the particular development proposals; funding; timescale etc.

The setting of appropriate, well defined and relevant objectives is crucial to all stages of the redevelopment of land affected by contamination. Lack of precision and/or clarity in setting objectives will inevitably increase uncertainties. This can lead to inappropriate conclusions being drawn and recommendations for further work which later turn out to be inadequate (i.e. the scope of work was underestimated) or unnecessary (i.e. an appropriately scoped Phase 1 would have negated the need for, or reduced the scope of, such further work). Objectives for Phase 1, the hazard identification stage therefore should include the following:

- to construct an initial conceptual site model;
- to enable a preliminary risk assessment;
- to inform the need for and scope of further work (desk based or intrusive investigations);
- to assess the potential for formal determination as Contaminated Land.

1.2 Site definition and description

Typically the information defining “the site” and providing an initial description will be provided by the land owner (or agent). This initial information will be supplemented by data gathered from other tasks as the desk study progresses. At the outset of any desk study it is crucial to understand the exact area occupied by the study site. Ideally a plan will be provided clearly showing the site’s boundaries however this is not always the case. Should only an address or grid reference be provided for a site confirmation of the site’s boundaries must be sought by requesting the client/site owner/agent etc. either to provide a plan showing the boundaries or annotate a plan provided by the report producer. Site ownership boundaries particularly on industrial sites can often not reflect boundaries as shown on contemporary maps and can form unusual shapes which are not intuitive. It is therefore inadvisable for the site boundary to be defined by anyone but the client or site owner. Incorrectly identified site areas can lead to significant errors in the assessment of risks and can result in abortive work (both costly and embarrassing to all parties!).

Typically a small scale plan showing the site boundaries will be accompanied by a large scale map showing the site location in a regional context. Ideally a national grid reference will also be provided. If the grid reference is not provided by the commissioning party, this must be identified, agreed and included in the desk study report.

Remember:
A site name (or even post code) is not a unique identifier. Your desk study may be on a site of the correct name, but it may relate to the wrong part of the country. A six figure National Grid Reference (NGR) uniquely identifies the a site and must be used to locate the land in question and must be stated in the report.

Having defined the site area, an accurate description of what currently occupies the area (i.e. buildings, hard standing, tanks) is required. This description should be kept concise but the location of sources of potential contamination such as tanks should be clearly defined. Where multiple similar features are present a suitable labelling system should be adopted and adhered to throughout the report (including figures). Descriptions of the condition of potential contaminating features such as tanks should also be made. The site description should include the following information:

- the lie of the land (topography)
- access to the site (i.e. names of roads, entrances etc.)
- the presence of any surface water features
- the proportion and make up of hard standing areas compared to areas of soft landscaping
- the layout of the site
- current site activities
- the nature of surrounding land uses
- information on any areas of identified contamination including those on surrounding sites should be listed.

1.3 History

1.3.1 Sources of historic information

Understanding the history of a site or parcel of land is crucial to understanding the potential for contaminants to be present on a site. It can also provide a useful indicator as to the likely location of those contaminants. The identification of the historic land uses of a site is usually determined utilising a number of sources of information. The most common sources are tabulated below (in alphabetical order) and described in more detail in the following text. A listing of useful sources is also given in CLR3 (Department of the Environment 1994a).

Although now rather dated (and thus not referring to some of the more recent data sources now available) the listing in CLR3 is an important reference to several sources of information not captured by the current commercial providers (see below).

Table 1.1 **Sources of historical information (in alphabetical order)**

Information source	Details	Contact details
Anecdotal evidence	Long-term employees and local residents can often shed light on the recent history.	
Bodleian Library, Oxford	Supplies A4 extracts of maps in 10 working days.	01865 277 013 www.bodley.ox.ac.uk
British Library, London	Map extracts of UK and parts of Europe available. Order maps prior to visiting.	0207 412 7700 www.bl.uk
Environment Agency	Provide data on licensable activities (e.g. waste management licences and pollution control permits).	www.environment-agency.gov.uk
Commercial third party environmental search providers	Provide historic maps and updated regulatory data electronically and in hard copy. [Does not currently cover N Ireland]	
Internet search engines	Can turn up data from a range of sources – best to use multiple search engines as they can produce very different results.	
Local Authorities	Hold records of past planning decisions, often intimate and detailed knowledge/records of land use. Hold information about historic landfills (provided via Environment Agency).	Planning, Environmental Health/ Protection and Building Control Departments
Local studies libraries	Can hold historic photos of the site. May have local historic accounts.	
National Library of Scotland Edinburgh	Maps extracts of most of the UK can be ordered on the day.	0131 466 3813
National Library of Wales Aberystwyth	Map extracts of the UK can be ordered on the day.	01970 632 800
Belfast Central Library	Map extracts of the N Ireland can be ordered/ viewed on the day.	028 9050 9100

Of these sources a quick and convenient method for obtaining the basic historic (and other) information is by purchasing maps from the commercial suppliers. This can be done via the internet within a short period of time. It is good practice for these products to form part of the Phase 1 report.

Remember:
Products from commercial suppliers, whilst a convenient and rapid source of data, on their own do not constitute a Phase 1 report. The assessment text that sometimes accompanies these otherwise factual reports is often highly caveated and caution should be used if reliance is to be placed on such text.

1.3.2 Historic maps

Background
The first comprehensive UK wide map series was produced by Ordnance Survey from the mid 1800s. The first maps were surveyed by County at a scale of 1:2,500 (1:25 inch) and are called the County Series. Later versions of the County Series were also available at a scale of 1:6 inch (1:10,560), which were superseded by 1:10,000 scale maps post decimalisation. Larger scale 1:25,000 maps are also available from Ordnance Survey from the mid 1800s though due to their scale they are of limited use. If required, earlier maps can be available for some areas though generally these are not commercially available but can be sourced via the libraries listed.

Mapped evidence of site history
Historic plans can provide the following information:

- the history of industrial and other uses of a site and the surrounding area;
- the type of industrial activity undertaken i.e. early Ordnance Survey maps often identify industrial uses such as acid works, gas works, or lead works whereas later (or large scale) maps often only label these features as ‘Works’ or ‘Factory’ etc.;
- the layout of the site, including locations of buildings and tanks etc. at the date of the map; and
- evidence of excavations and infilling (e.g. mounds of material and earthworks).

When reviewing historic maps, as well as the obvious labelling identifying historic use of the buildings on the site, there is often other relevant information to be gained from their study. For example:

- distinctive names such as Gasworks Road, Clay Pit Lane etc. shown on maps indicate the former presence/proximity of such potential sources of contamination;
- the disappearance of cut features such as pits and quarries or water features such as canal basins or ponds can indicate land filling;
- re-routed water courses will indicate linear areas of infilling;
- care must be taken when interpreting slope marking symbols (which sometimes are not well defined) as it is very important to interpret spoil heaps or excavation features correctly.

The identification of site history from historic maps must be undertaken diligently. It is wrong to assume that this is a simple task that can be undertaken by untrained staff. The interpretation of mapped information requires care, precision and understanding. Important information regarding the meanings of abbreviations and symbols used on Ordnance Survey maps is given in CLR3 (Department of the Environment 1994a) to which appropriate reference must be made.

Description of site history
For the purposes of clarity and accuracy the reporting of historic reviews should be divided into two sections; on-site history and off-site history. All comments should be in chronological order starting with the oldest information. It is important that factual mapped information is accurately reported. For example, where the use of buildings have not been specifically identified the feature could be described as “a large (20,000m^2 approx) unlabelled building likely to have been of commercial/industrial use”.

Evidence of activities within the site boundary should be recorded and dates when features appear/disappear should be stated. Activities and features of note include all potentially contaminative land uses as well as pits, ponds, quarries, railway cuttings etc. which may have been filled. When describing features within the site boundary the text must avoid ambiguity. This can be achieved by using the term ‘in’ (i.e. “tanks were present in the north of the site”) rather than ‘to’ which could suggest features off-site (i.e. “tanks were present to the north of the site”). It is also important that the reported age of activities/features is accurately given. For example if a petrol station is shown on the 1965 map, but is not recorded on the 1935 map the most appropriate description is “A petrol station was constructed on the site at sometime between 1935 and 1965”. It is misleading to imply that the petrol station dated from 1965 (i.e. “a petrol station was present on-site from 1965”) as this could affect the period, extent and nature of the contamination.

Typically off-site historical descriptions should be concentrated on an area up to 250m around the site boundary. Features at greater distances should only be described if they are particularly large or have the potential to affect the land quality at the site (e.g. landfills) or the wider environmental quality of the site (e.g. power stations, large facilities such as oil refineries etc.). The distance and direction from the site boundary should be given as part of any off-site feature described. Particular care should be taken when defining the distance of a landfill from the site as it is most important to measure from the nearest landfill boundary rather than the central location of the landfill.

In report text describing both on and off-site histories there can be a tendency for features which have no potential to cause contamination (i.e. roads, housing etc.) to be overly detailed. This can make the history excessively long and can detract from the features which are of potential concern. In such cases general comments such as “the area becomes developed with housing by 1980” can be made which adequately demonstrate an awareness of this history without detracting from an appropriate focus on land quality.

It is good practice to include a copy of all available maps in reports. An example of a site history is presented in CLR3 (Department of the Environment 1994a).

Caveats

It is important to remember that historic maps (and plans) do not provide a comprehensive description of a site’s history. They provide details of the site from a date prior to the publication of the map (i.e. a snapshot in time). The period between map editions can be substantial (i.e. several decades). Not all map series are available for every date range in many areas of the UK and therefore there will be gaps in this mapped record for some sites. Potentially contaminative land uses could have come and gone in such periods and may therefore not be a part of this particular record. In addition, there will be potentially contaminative land uses which do not make it on to the map record, for example, small scale storage/use of hazardous materials, illegal/unlicensed waste disposal activities etc.

Different map series do map different features utilising differing symbols which can result in features disappearing from maps which may have remained on-site. Some features are also not mapped for security reasons such as airfields and other military installations. These areas are mostly shown as blank white areas on the map. This absence of any mapped information can be conspicuous and in such cases, there may often be clues in the map record. For example, the first record of an airfield or flying club on a map dating from the 1950s should be taken as an indication that this may have been a war-time airfield, occupied by the Ministry of Defence or the USAF and thus subject to further enquiry.

1.3.3 Historic aerial photos

Historic aerial photographs are available for most UK cities and are available from a number of specialist commercial providers including the Ordnance Survey www.ordnancesurvey.co.uk. There are also a series of aerial photographs taken between 1939 and 1954 by the Luftwaffe, RAF and USAAF which are available from various third party commercial companies and can prove invaluable in identifying features that are poorly mapped or are unclear such as spoil heaps and pits.

1.3.4 The internet

The internet can, on occasion, prove to be an invaluable source of a variety of information on the local area and/or the activities of a site. The use of search engines can enable rapid and easy access to relatively obscure data which otherwise would be very difficult and/or time consuming to source. However, in addition to authoritative/accredited information there is also the potential for erroneous or mischievous data to be retrieved from internet searches.

Remember:
The reliability of all information sources should always be carefully assessed and the source of any such data properly referenced in the report.

Examples of useful web sites include www.controltowers.co.uk which holds historic and current details of war time airfields. This can prove particularly useful as these airfields are ‘blanked out’ on historic maps. A source of near current detail of a site can be obtained from digital satellite imagery of the earth’s surface via an internet search engine. Reference to this photography can be useful in site orientation prior to or during a site walkover survey and also for subsequent reference (although the user should always determine the date of such imagery as it can be several years old).

Internet search engines should also be interrogated for accounts of local history. For example searching for a named factory/location will often reveal useful very detailed accounts of land use providing site specific data on the nature and extent of potential contamination associated with activities on the site.

1.3.5 Local Authorities

Local Authorities retain a great deal of publically available data that could prove useful for assessing the history of a site (usually at a relatively modest cost). It can however take some time for this information to be sourced from the Authority. Information available on potential use includes: details of planning consents, the planning register, information held by the environmental protection team and information of past landfilling activities.

1.3.6 Libraries

As well as the national libraries listed in Table 1.1 above, local studies libraries can provide a service that allows a search of their records for relevant documentation. These can include books, local newspapers, local photographs and historic accounts not available from other locations. Some industrial/former military sites have histories written by former employees which can prove extremely useful however such documents are not commonly available. Additionally, in particular regions or for certain topics, there may be specialist books or publications which provide invaluable data. For example in London, books such as The Lost Rivers of London (Barton 1992a) and The London County Council Bomb damage maps (Saunders & Woolven 2005a) are essential references. Similarly, 'The Mighty Eighth' (www.mightyeighth.org) provides details on the activities of the US Army Air Force based in the UK during World War II. Books and other publications which may be difficult to find are accessible via Inter Library loan.

1.3.7 Other sources

As described above (Section 1.3.1) other sources of information are listed in CLR3 (Department of the Environment 1994a). Detailed accounts of site histories may also be available from the corporate entities who previously occupied the site and in many cases have carried out their activities for many decades. For example, detailed accounts of many of the former gasworks are available from British Gas properties, details of steelworks from Corus, information on coal mining activities from the Coal Authority. The Law Society and Coal Authority have published a Directory (and guidance) of coal mining and brine subsidence claims (Law Society 2006a).

Anecdotal evidence of the past uses of a site can also be obtained (often by a walkover survey – see below) from people who either worked on a site and/or who lived in its vicinity. Although care should be exercised in the use of such information (and its anecdotal nature must always be appropriately reported) such data can be invaluable and may not be available from any other source.

1.4 Current use

Details about the current site use can be determined from a number of sources however a critical element in determining the current use of a site is the undertaking of a site walkover survey.

1.4.1 Site walkover survey

Site walkover surveys should be conducted utilising an aide memoire (site visit questionnaire) which is tailored to the type of site being audited i.e. active single use site, derelict or non-operational site, industrial estate etc. An example of such a questionnaire is given in Annex 1. Such surveys should be carried out only after essential base data has been obtained and assessed (see Section 1.2). A camera should always be taken on a site walkover. Photographs should be taken of; potential contamination sources, areas of visual contamination, of the site area as a whole and of any 'unusual' features (i.e. plants which are suspected to be Japanese

Knotweed, possible vent stacks, unusual grid patterns on the site surface, manholes and possible breather pipes etc.) current activities and standards of housekeeping etc.

There may be health and safety aspects associated with carrying out walkover surveys (e.g. lone working on derelict sites, sites with no power/lighting where internal access is required) and these should always be determined prior to the visit. Many organisations will have their own procedures for working in such circumstances to ensure the welfare of the surveyor, which normally includes as standard practice the availability of a mobile phone on all site walkover surveys.

The objectives of a site walkover survey will vary to reflect the specifics of both the site itself and also the nature of the project. Typically, the objectives will include the following:

- to identify and assess visual and olfactory evidence of contamination e.g. staining of concrete/soils, odours, presence of gas protection measures etc.;
- to identify locations of potential sources of contamination and assess their condition i.e. tank location, presence/condition of secondary containment/bunds, location of fill points, process areas etc.;
- to identify surrounding land uses and any potentially contaminating activities;
- to identify/verify the presence of potential receptors (on- and off-site) which may be affected by the identified sources;
- to obtain information on activities/procedures and standards of housekeeping etc. (e.g. by interview with a site manager or appropriate staff and review of site environmental records); and
- to assess site access and potential investigation locations and constraints.

Remember:
It is highly desirable that the site walkover survey is carried out subsequent to the initial determination of historical use. This enables any features identified by the map review to be examined and assessed on the ground. For example, areas of adjacent off-site quarrying – are those quarries still holes in the ground? Have they been infilled? Have they been developed and if so is there evidence of remediation measures? etc.

1.5 Environmental setting

1.5.1 Identification

The determination of a site's geological, hydrogeological, hydrological and ecological setting (and that of the surrounding area) is a crucial element of the Phase 1 work. These factors need to be determined to establish the vulnerability of the site with respect to the potential for contamination of the surface and sub-surface aqueous environments. Typical data requirements and the sources of such data needed to inform the subsequent sensitivity assessment are summarised in Tables 1.2 to 1.6 below. The availability of information may vary greatly between sites.

Table 1.2 Topography

Key information	Sources
Elevation of site in metres above Ordnance Datum;	Ordnance Survey maps (various scales);
Location relative to nearest built up area or prominent geographical feature;	Aerial photography;
Landscape description such as slope of land; abrupt changes of slope, cuttings and embankments etc. (e.g. slope down to river can give an indication of both surface water run-off direction but also local groundwater flow).	Visual observations from walkover survey.

Table 1.3 Geology

Key information	Sources
Made Ground – nature, thickness and variability.	Previous site investigations. 1:10,000 British Geological Survey (BGS) maps (1:50,000 maps can show significant areas of made ground e.g. landfills).
Drift (including recent unconsolidated deposits such as glacial and river deposits) – strata, description, thickness.	BGS maps (typically also include vertical and horizontal cross sections and may indicate depth to solid geology). BGS regional appendices (accompany 1:50,000 scale maps). Institute of Geological Sciences (predecessor to the BGS) Mineral Assessment Reports (accompany 1:25,000 maps of areas where sand and gravel deposits exist, include strata description, borehole logs, photographs). Last published in 1990, available directly from the BGS (01159 363241) but not currently on general sale. May be stored in public libraries.
Solid strata, description, thickness, relevant structural information (e.g. faulting, folding).	BGS maps (typically also include vertical and horizontal cross sections and may indicate depth to various strata). Borehole logs (BGS).
Mining – is the site within the zone of influence of current or former below ground or opencast mine workings, mine entries, subsidence.	BGS maps. The Coal Authority.
Radon – is the site in an area of radon potential.	Indicative Atlas of Radon in England and Wales [www.bre.co.uk/radon/protect.html]. Radon in dwellings in Scotland 1996. Radon in dwellings in Northern Ireland 1999.

Table 1.4 Hydrogeology

Key information	Sources
In England, Wales and Northern Ireland. Aquifer Classification; Scotland does not have a formal classification system comparable with that of England and Wales although SEPA is now classifying groundwater bodies for the purpose of the WFD. Soil vulnerability.	Environment Agency Groundwater Vulnerability maps (1:100,000) and accompanying regional appendices. In Scotland, Hydrogeological Map of Scotland BGS 1:625 000 and for soil vulnerability 1:625 000 Groundwater Vulnerability Map of Scotland.
Groundwater flow mechanisms; Groundwater flow direction and depth; Surface water/groundwater interaction; Groundwater quality.	BGS Hydrogeological maps (only cover parts of country where significant groundwater exists).
Groundwater abstractions (within a minimum of 1km of the site boundary).	Environment Agency records*. Commercial providers of regulatory search reports. Local Authority (hold records of private generally domestic unlicensed abstractions where known).
Source Protection Zones.	Environment Agency website. Commercial providers of regulatory search reports.
Discharges to ground, pollution incidents to groundwater.	Regulatory search report providers such as Landmark and GroundSure. Environment Agency*.

* requires written request for information, in letter or email form. Information will be chargeable and can take up to 3 months to be provided. Charges and response time vary with volume of information requested.

Table 1.5 Hydrology

Key information	Sources
Nearby surface watercourses and local surface water network (proximity to site and flow direction); Proximity to coastal waters.	Ordnance Survey maps
Surface water abstractions; Licensed discharges and pollution incidents to surface water.	Environment Agency records Commercial providers of regulatory search reports
River quality [RQO (river quality objectives) including chemical assessment criteria].	Environment Agency website www.environment-agency.gov.uk
Flood zones.	Environment Agency website www.environment-agency.gov.uk
Coastal waters [presence of marine nature reserves (MNRs), Special Area of Conservation (SACs), Special Protected Area (SPAs)].	Natural England website www.naturalengland.org.uk ('nature on the map' section)

Table 1.6 Ecology

Key information	Sources
Sites with ecological designations within 1km National Nature Reserves (NNR) Local Nature Reserves (LNR) (Local Authority Nature Reserves in Northern Ireland) Sites of Special Scientific Interest (SSSI). Areas of Special Scientific Interest (ASSI) in Northern Ireland) National Parks Areas of Outstanding Natural Beauty (AONB) (National Scenic Areas in Scotland) Special Areas of Conservation (SAC) Heritage Costs Ramsar Sites Special Protection Areas (SPA) Regional Parks (Scotland Only) Likelihood of the presence of protected species on-site	Commercial providers of regulatory search reports Natural England Scottish Natural Heritage Countryside Council for Wales Environment and Heritage Service

1.5.2 Assessment of site sensitivity

The sensitivity (vulnerability) of the site is then assessed on the basis of this data set, which will also enable identification of potential contaminant migration pathways. It is important that the characterisation of site sensitivity is logical, transparent, robust and repeatable. A scheme describing terms of sensitivity for groundwater, surface waters and ecology is presented in Annex 2. The assessment of site sensitivity by personnel with an appropriate, relevant technical background will increase the technical rigour and repeatability of the assessment. For example description of a site where the groundwater sensitivity has been classified as "High" could be as follows:

> *"The site is underlain by a Major Aquifer with groundwater abstraction within 1km. This groundwater is likely to provide baseflow to a sensitive watercourse less than 100m from the site boundary. The site is within the Source Catchment protection zone (Zone II)."*

The sensitivity of particular receptors at/adjacent to the site must then be taken into account during the subsequent risk assessment.

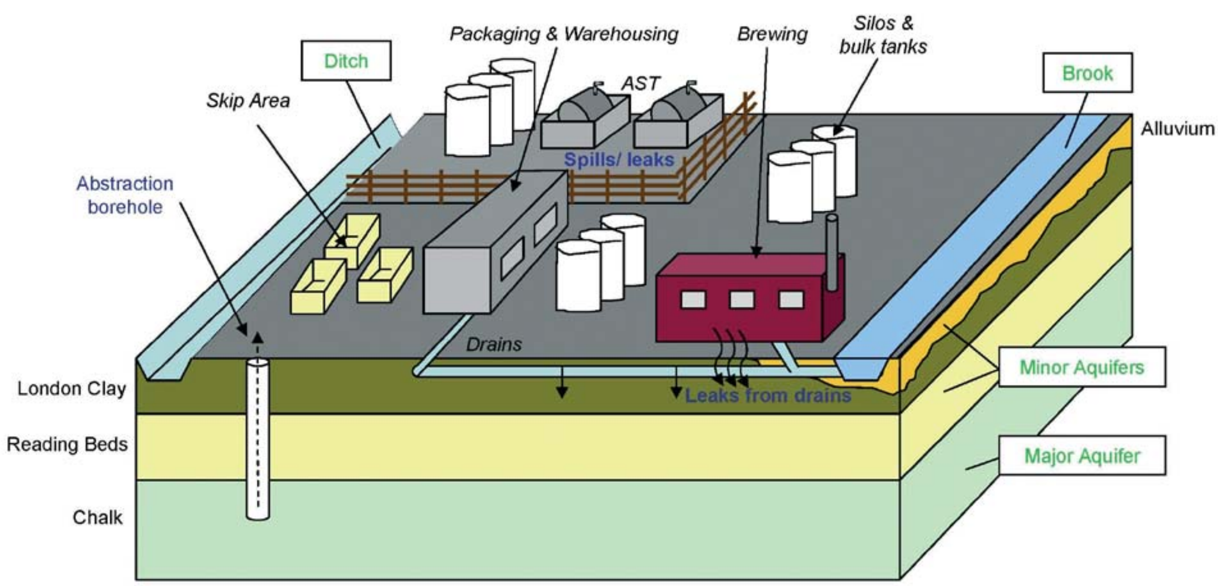
1.6 Initial conceptual site model

The following text from Model Procedures (Defra/Environment Agency 2004a) describes how the Phase 1 information (including data from the site walkover survey) is combined to develop an initial conceptual site model. *"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."*

Getting the conceptual site model right and demonstrating a clear understanding of all potential pollutant linkages at this stage is crucial. It can then be used as a basis for designing a ground investigation, which tests the conceptual site model. If any potential pollutant linkages are missed then the site investigation is unlikely to be sufficient. Areas of uncertainty, e.g. exact location of former land uses or unknown ground conditions, also need to be highlighted. The conceptual site model is a device for improving our understanding of something, in this case the pollutant linkages identified for a site. It summarises the nature of a problem for which a solution is being sought.

The format of the conceptual site model is likely to be based on the complexity of the site. For instance the pollutant linkages associated with a residential house in an undeveloped area located directly on a Non Aquifer with no nearby watercourses may be easily described in words. However, increased numbers of pollutant linkages may be easier explained in a table or 3D cross section, or a combination of both.

Figure 1.2 Example initial conceptual site model



1.6.1 Contaminant sources

Potential contaminants associated with former and current land uses and other local factors need to be established. Naturally occurring contaminants can be associated with particular geologies. Contaminants can also migrate from adjacent land uses. The Department of the Environment's Industry Profiles describe specific industrial processes and the chemicals that are commonly found on industrial land. A summary of this information is given in CLR8 (Environment Agency 2002b) and also in R&D66: 2000 (reproduced here in Volume 2 Annex 3). However, not all contaminants listed with a particular land use will require assessment on all sites. For instance chloride is an essential micronutrient and is not considered an important contaminant in most soils, although it may be toxic to plants and have a detrimental effect on the performance of building materials at elevated concentrations (Environment Agency 2002b). Some sites may have significant concentrations of contaminants not indicated for a particular land use due to their infrequent occurrence, e.g. some toxic chlorinated solvents (used as degreasers). The opinions of a chemist or similar specialist should be sought at this stage to confirm the main contaminants of concern.

1.6.2 Receptors

Information on receptors may be obtained from the site walkover, the environmental setting and any proposed development plans. On any particular site, receptors can include any or all the following:

- human health (e.g. site occupants, adjacent land users, maintenance workers, trespassers);
- water environment (e.g. groundwater, surface water, coastal waters, artificial drainage);
- ecosystems (e.g. flora and fauna); and
- construction/building materials (including services).

Consideration should be given to how each receptor may be affected by the identified contaminants and to the sensitivity of that receptor. For example, separation of 'site residents' may be required into a number of more specific classes, such as; adults, children and elderly people for example. Similarly, groundwater resources would be sub-divided into Major and Minor Aquifers, to reflect their respective sensitivity (see Annex 2). Certain determinands have greater significance for some receptors than others. For example, phytotoxic metals such as copper and zinc can affect flora at much lower concentrations than those of concern to human health. The Industry Profiles and CLR8 identify receptors which are most likely to be at risk from exposure to these contaminants.

1.6.3 Pathways

The pathways by which a sensitive receptor may be exposed to a contaminant source can be identified from the earlier desk study. Geological maps can provide information on the presence of permeable strata through which contaminants present at the ground surface could migrate to groundwater. Exposure to contaminant sources can be either direct or indirect as indicated in Table 1.7 below.

Table 1.7 Examples of potential exposure pathways

Receptor	Direct pathways	Indirect pathways
People (Human Health) and animals (fauna)	Direct contact, dermal absorption, soil ingestion	Inhalation of dust/vapours, ingestion of fruit and vegetables and/or waters; migration of hazardous gases/vapours via permeable strata
Controlled waters	Spillage/loss/run off direct to receiving water	Migration via permeable unsaturated strata, run off via drainage/sewers etc.
Flora (plants)	Direct contact with contaminated soils	Uptake via root system, migration of hazardous gases/vapours via permeable strata
Buildings and structures	Direct contact with contaminated soils	Migration of hazardous gases/vapours via permeable strata

1.6.4 Updating the conceptual site model

The conceptual site model is likely to change to reflect the situation for an existing development and during/after proposed development. It is important that the model is updated with new information as the investigation, risk assessment, selection of remediation measures and implementation of risk management proceeds. For example, a model based on the risk of exposure of occupants of future development to contamination in soil by direct contact would need to be modified if, during ground investigation, waste deposits capable of producing landfill gas were encountered. The risks associated with accumulation of gases in confined spaces would then need to be considered. Further investigations of gas concentrations in the ground may be required, and the data from these may result in further amendments to the conceptual site model to reflect a new pollutant linkage.

The conceptual site model might also be updated if the form of the proposed development is changed. For example on a development incorporating private gardens that could be cultivated by residents for vegetables the conceptual model could include identification of toxic heavy metals to which residents could be exposed by eating contaminated produce. On a site with no private gardens and managed public open space, consumption of vegetables grown in contaminated soil may not be a relevant pollutant linkage.

Remember:
The conceptual site model is the key to the development of a proper understanding of land affected by contamination. Such a model must inform all three phases of work. An inadequate understanding of the conceptual site model will inevitably give rise to errors, delays and inefficiencies in subsequent enabling or development activity.

1.7 Preliminary risk assessment

Contaminated land risk assessment is based on development of a conceptual model for the site. As discussed in Section 1.6 the initial conceptual site model is a representation of the relationships between contaminant sources, pathways and receptors developed on the basis of hazard identification. Risk assessment is the process of collating known information on a hazard or set of hazards in order to estimate actual or potential risks to receptors. The guiding principle behind this approach is an attempt to establish connecting links between a hazardous source, via an exposure pathway to a potential receptor, referred to as a ‘pollutant linkage’. The objective of a Preliminary Risk Assessment is to identify the nature and magnitude of the potential risks. This involves consideration of:

- each potential pollutant linkage (contaminant source – pathway – receptor);
- current status of the site, construction activity, proposed new use etc.;
- short-term (acute) and long-term (chronic) risks;
- uncertainty (does enough data exist to provide confidence in the assessment?).

This approach is in accordance with the Statutory Guidance on Contaminated Land (Defra 2006a, WAG 2006a and Scottish Executive 2006a) and the Model Procedures (Defra/Environment Agency 2004a).

Risk is based on a consideration of both:

- the likelihood of an event (probability) [takes into account both the presence of the hazard and receptor and the integrity of the pathway]; and
- the severity of the potential consequence [takes into account both the potential severity of the hazard and the sensitivity of the receptor].

A pollutant linkage must first be established before tests for probability and consequence are applied. If there is no pollutant linkage then there is no potential risk. For example, when assessing the risks to groundwater from surface contamination at a site where groundwater is present within a Major Aquifer which is overlain by clay of significant thickness (say for example

50m) and there are no development proposals to penetrate the clay, then there is no plausible pollutant linkage. Consequently, the risks to the Major Aquifer need not be subject to formal risk assessment. In such circumstances, reports should clearly state the source and the receptor but state that because there is no linkage there is no risk.

There is a need for a logical, transparent and repeatable system in defining the categories of severity of consequence and likelihood as well as for the risk itself.

Severity (consequence) can be defined as the adverse effects (or harm) arising from a defined hazard, which impairs the quality of human health or the environment in the short or longer term. For example a consequence defined as *"Severe"* could be defined as *"Highly elevated concentrations likely to result in 'significant harm' to human health as defined by the EPA 1990, Part 2A, if exposure occurs"*. The type and form of the contaminant needs to be known in order to understand the effect on humans and therefore severity of potential harm. For instance different forms of cyanide behave differently. Complex cyanide (*"blue billy"*) is relatively "non toxic" whereas free cyanide is "highly toxic" (Environment Agency 2002b).

Probability can be defined as the chance of a particular event occurring in a given period of time. For example, a *"High Likelihood"* could be defined as *"where an event would appear very likely in the short-term and almost inevitable over the long-term, or there is evidence at the receptor of harm or pollution"*.

A scheme defining the various categories of severity and likelihood, based upon CIRIA 552 (CIRIA 2001a) is presented in Annex 4.

1.7.1 Risk classification

Once the consequence and probability have been classified for a pollutant linkage they can be compared to produce a risk category from "very high risk" to "very low risk". It is not possible to identify a risk rating of "no risk" as the acceptability of risk may depend on the viewpoint of the stakeholder concerned. It may be necessary to deal with a risk even if it is "very low" although this action may not be urgent. The following classification of risk has been developed to assist in qualitative assessment of potentially unacceptable risks.

Table 1.8 Categorisation of risk

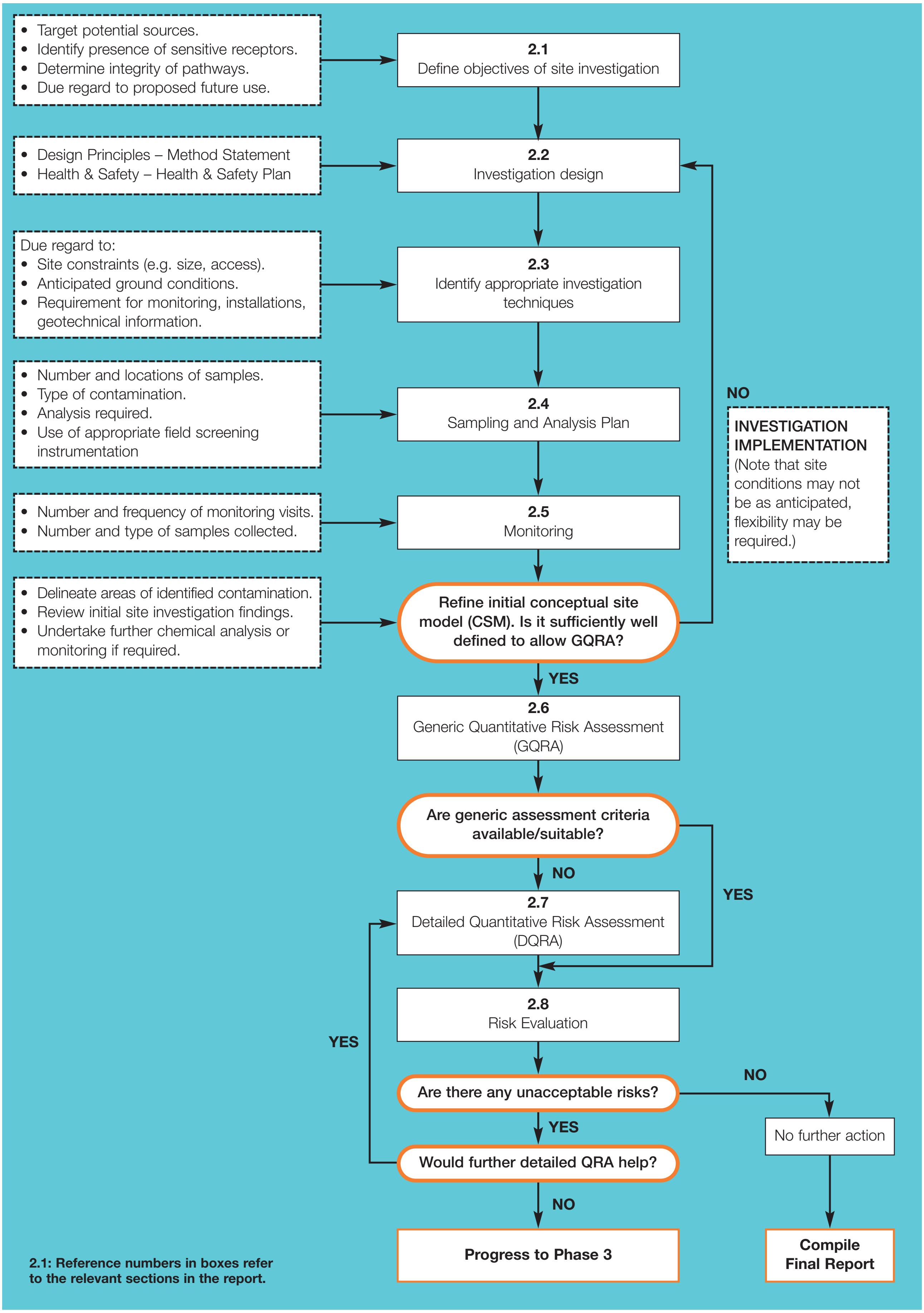
		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability (Likelihood)	**High likelihood**	Very high risk	High risk	Moderate risk	Low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

It is also important that these terms describing the various levels of risk are appropriately defined. The definitions set out below are also taken from CIRIA 2001a. These are not "statutory" definitions and other terms may be used, provided that appropriate definitions accompany the terms of risk description.

Table 1.9 Description of risk levels

Term	Description
Very high risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
High risk	Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
Moderate risk	It is possible that without appropriate remediation action harm could arise to a designated receptor. It is relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely that such harm would be relatively mild.
Low risk	It is possible that harm could arise to a designated receptor from an identified hazard. It is likely that, at worst if any harm was realised any effects would be mild.
Very low risk	The presence of an identified hazard does not give rise to the potential to cause harm to a designated receptor.

Chart 2 Phase 2: Risk estimation and evaluation



Phase 2
Risk estimation and evaluation

2.1 Objectives

2.1.1 General

The overall aim of the work in Phase 2 is to estimate and evaluate the potential risks that have been identified in the Phase 1 Desk Study. The process of risk estimation and evaluation therefore begins with the initial conceptual site model and progresses by means of various field, laboratory and office based activities to refine that model and thus determine those risks which are potentially unacceptable as illustrated in Chart 2 [and by the Case Study, Chart 2A in Volume 2].

The process of risk estimation and evaluation thus comprises:

- Definition of objectives [Section 2.1.2];
- Design of the investigation [Section 2.2];
- Employment of appropriate investigation techniques [Section 2.3];
- Sampling and analysis [Section 2.4] and monitoring [Section 2.5];
- Quantitative risk assessment [Section 2.6].

The testing and refinement of the initial conceptual site model will be achieved either by further more detailed desk based study and/or by an appropriately focussed site investigation. The site investigation, must be informed by the data obtained during the Phase 1 desk study and will therefore be designed to test all of the identified potential pollutant linkages.

Aspects of the conceptual site model additional to the presence, extent (lateral and vertical) and concentrations of contamination must also be addressed in Phase 2. For example, as well as the determination of the site geology and hydrogeology, the physical parameters of both the soil and groundwater regimes must be investigated (e.g. density, particle size distribution, porosity, hydraulic conductivity etc.).

Remember:
Wherever possible, site investigations should combine aspects of both contamination and geotechnics (AGS 2000a).

2.1.2 Definition of objectives

Setting appropriate objectives which encompass both the geotechnical and geoenvironmental aspects without compromising the requirements of each discipline is crucial. If the objectives are not well determined, inefficiencies will be inevitable, in the worst case involving omission of vital data or duplication of work. Typically the objectives would include:

- Determination of the ground conditions (soil and rock strata, groundwater);
- Determination of geotechnical, geochemical and radiological conditions (of soils and water);
- Determination of the soil gas regime;
- Determination of unacceptable risks.

The objectives, must also:

- be framed to address the overall aims of the particular project;
- be well defined and appropriate;
- reflect the particulars of the planned use of the land (continuation of current use or its redevelopment);
- take account of any site specific issues or constraints.

For example, an appropriate objective might be; *"To determine the physical and chemical nature of the near surface (<1m) soils"*. Such a well defined objective will enable the site investigation designer to ensure that both the method of investigation and the sampling and analysis plan can be designed to ensure that the objective is achieved.

An example of an inappropriate objective (which superficially may appear similar) is *"To dig ten trial pits"*. It is clear that this objective could be satisfied, but with completely inadequate results as it would not relate to the conceptual site model, the site investigation design or the overall objectives of a particular project.

The objectives, once identified should be described in writing and included in the final report.

2.2 Investigation design

2.2.1 Design principles

As described above a site investigation must be designed to test all elements of the initial conceptual site model (i.e. potential sources, pathways and receptors). The investigation design must also take into account any site specific constraints (many of which will also have been identified in the Phase 1 work). The extent of the site (in three dimensions) must also be reflected in the site investigation methodology. Typically a well designed site investigation will employ a number of the available techniques (described in 2.3 below) in combination, to ensure the various objectives are addressed.

In designing a site investigation, consideration must be given to:

i. the aerial extent of the site and its accessibility;
ii. the depth intervals occupied by the strata of interest;
iii. any specific locations of potential contaminant sources;
iv. any parameters that will vary with time;
v. the presence of controlled waters (groundwater or surface water bodies) which could form contaminant migration pathways or could be receptors to any contamination;
vi. the soil gas regime;
vii. any potential contaminant sources with 'unusual' properties (e.g. dense phase non aqueous liquids which will sink through an aquifer to the top of an aquiclude and then migrate following gravity rather than groundwater flow direction);
viii. any potential contaminant sources which should also be investigated by on-site measurement (e.g. volatile compounds or radionuclides etc.);
ix. particular sampling techniques/storage vessels necessary to recover and maintain the integrity of particular contaminants;
x. the site investigation health and safety plan (which must reflect the potential hazards identified in the Phase 1 desk study);
xi. the need for on-site environmental monitoring (e.g. of site personnel, dust etc.);
xii. time, budget and any other particular site constraints.

Almost inevitably there will be conflict between the possible design responses to such issues. Often a balance is achieved by designing the investigation (including the chemical analysis) in phases (CIRIA 1995a, British Standards 1999a and British Standards 2001a, Environment Agency 2001a).

The usual sequence is:

i. An exploratory site investigation designed to prove the basis of the ground model; to confirm the existence (or absence) of potential hazards suspected from the Phase 1 study and to provide a level of data across the whole of the site area;
ii. A detailed (or main) investigation designed; to better define the ground model; to describe in more detail the nature and extent of identified contamination (in three dimensions); to confirm areas where contaminants are absent/below relevant thresholds); to examine areas of unusual variation; to focus on particular contaminant types etc.;

iii. A supplementary investigation designed to fully define particular facets of the conceptual model (often linked to the design of remediation treatment etc.).

Not all site investigations will require all of the three phases described above. It may be the case that an exploratory level site investigation provides sufficient data to enable an appropriately rigorous risk assessment and assessment of the need for and scope of remediation treatment. Often, on sites where limited (if any) potential pollutant linkages have been identified in the Phase 1 work, a site investigation carried out primarily for geotechnical purposes, may also include a limited exploratory level of investigation of contamination for confirmatory purposes.

2.2.2 Health and safety

Health and safety is the responsibility of everyone involved to ensure that site investigations are managed and conducted safely. There is a substantial body of legislation to be considered and adhered to in site investigation to minimise risks to the health and safety of the site workers, visitors, neighbours etc. All intrusive site investigations are governed by the Construction (Design and Management) Regulations (CDM) 2007 (HSC 2007a and associated Approved Code of Practice (HSC 2007b)) which came into force in 2007. The key aim of these Regulations is to integrate health and safety into the management of the project and to encourage everyone to work together to:

- Improve project planning and management resulting in improved competence, cooperation, communication, coordination and control;
- Ensure efforts related to Health and Safety are targeted where they can do the most good and reduce bureaucracy; and
- Identify hazards early, so they can be eliminated or reduced at the planning and design stage and that residual risk can be mitigated.

For all site investigations a risk assessment should be carried out. This risk assessment will form the basis of the Health and Safety Plan. This document should include details of the residual risks, how they are to be mitigated e.g. safe working procedure, individuals' responsibilities and contact details for emergency services, utility companies and key personnel. The Health and Safety Plan is a living document and should be kept on-site and updated as necessary. Tool box talks should be held to ensure that all people working on the site are competent, and aware of safe working procedures and residual risks. Where more than one party is working on a site each group must cooperate and coordinate their work to reduce health and safety risks and ensure safe working procedures are adopted.

A common hazard associated with site investigations is the presence of underground services. Sufficient time must be allowed to obtain sub-surface service plans (water, gas, electric etc.) from the appropriate utility companies. Safe systems of working must be adopted for working in areas where such services exist (HSE 2001a). A similar approach must be adopted when working in the vicinity of overhead services (HSE 1997a).

Remember:
Health and safety is everybody's responsibility.

2.2.3 The Sampling and Analysis Plan

The Sampling and Analysis Plan is an essential tool in the site investigation design [see CLR4 (Department of the Environment1994b), CIRIA (1995a), BS 5930 (BSI 1999a), Environment Agency (2001a), BS10175 (BSI 2001a) and AGS (2000a)].

Such a plan should describe the locations of all sampling points (in three dimensions) and provide appropriate justification (i.e. **why** something is being done). It will include broad definition of any instrumentation to be installed in boreholes etc. (e.g. groundwater or soil gas monitoring wells). It will describe any particular requirements for sampling (e.g. volume of sample, type of vessel, use of preservative etc.). Such a plan may also describe the monitoring regime (e.g. for groundwater level and chemistry, or for soil gas) although this may also be in a separate document. Further information on the design of groundwater monitoring is given by the Environment Agency (2006a) and for soil gas monitoring by CIRIA (2007a).

The design of a Sampling and Analysis Plan typically combines two elements:

i. Targeted sampling [sampling is focussed on known or suspected sources of contamination];
ii. Non targeted sampling [sampling is carried out systematically on a grid defined in terms of pattern and spacing. Detail about such systematic sampling strategies is given in CLR4 (Dept of Environment 1994b)].

The decision on whether to adopt one or other of these elements or to utilise them both in combination must be based upon the conceptual site model. That is; an understanding of the ground conditions, the contaminant sources, the potential migration pathways, the averaging area(s), how the data is to be interpreted, the requirements of the risk assessment as well as the development plan itself. It will of course also reflect aspects such as the time available, site constraints (e.g. presence of buildings/structures etc.) as well as cost. Notwithstanding the importance of these aspects, the critical influence must be that of the conceptual site model.

The conceptual site model must also inform the density of sampling. There is no “standard” sampling density for any particular phase of site investigation. Typically, the exploratory level site investigation will utilise a lower density (i.e. a larger spacing say 50m to 100m centres) than the detailed investigation (where spacing of 20m to 25m has been referred to (British Standard Institute 2001a). However the British Standard also emphasises the importance of site specific factors and the conceptual site model. For example, such a pre-defined spacing may be inappropriate for a site of very large of very small aerial extent. A larger spacing may be appropriate for a site where the ground conditions are more uniform/predictable. A tighter grid may be required where ground conditions are suspected to be highly variable or where localised areas of contamination are suspected. Judgement must be used to determine an appropriate sampling and analysis plan. Such judgement will need to take into account all of the factors described above, most particularly the specifics of the conceptual site model.

2.2.4 Uncertainty

No matter how many samples are taken and how much chemical analysis or monitoring is undertaken there will always be elements of uncertainty with respect to the ground conditions and the chemistry of the various strata, the groundwater and surface waters as well as the soil gas regime. This uncertainty reflects not only the partial nature of the sampling, the heterogeneous nature of many soils being investigated, but also temporal variations. This uncertainty needs to be considered in all subsequent stages (i.e. risk assessment, remediation design and implementation) and by all relevant parties. It is useful to quantify the levels of uncertainty that are associated with any particular site investigation design. The report CLR4 (Department of Environment 1994b) described a simple procedure for estimating the confidence level of identifying a “hotspot” of contamination for particular sampling grids. It is a salutary lesson that on a 1 hectare site even with 150 sampling points on a herringbone pattern there is still a 5% chance that the investigation will not detect a localised area of contamination occupying 100m^2. [More detailed information on the uncertainty associated with soil sampling and its quantification has been the subject of considerable research (Taylor and Ramsey 2004a and 2005a). This level of uncertainty is then compounded by consideration of the actual volume of soil sampled and analysed (typically a very small proportion [tiny fractions of a percent] of the whole soil mass) as well as uncertainties in the laboratory analysis (see Section 2.4 below).]

Remember:
A well designed site investigation aims to reduce uncertainty to a reasonable minimum whilst recognising that it exists and then taking it into account during the subsequent decisions on risk assessment, remediation design, verification etc.

2.3 Investigation techniques

2.3.1 Selection

Detailed guidance on-site investigation techniques is given in the two relevant British Standards. BS5930 (BSI 1999a) presents a code of practice for site investigations. BS 10175 (BSI 2001a) describes the code of practice for the investigation of potentially contaminated sites. Other sources of information about site investigation techniques are presented in documentation published by the Environment Agency (2000b), CIRIA (1995a) and the AGS (2000a). As described above, the techniques selected will be determined by consideration of the objectives of the site investigation together with the conceptual site model and any site specific constraints.

The choice of techniques(s) adopted will therefore reflect amongst other issues:

- Access;
- The presence of buildings, structures and hardstanding;
- The nature of activities on the site (i.e. operational or vacant etc.);
- The strata anticipated, depth to water table etc.;
- The sampling and monitoring regimes anticipated; and
- The time period and budget available.

Site investigation may involve both intrusive and non intrusive methods. Non intrusive methods can be useful because they are not disruptive and can cover relatively large areas rapidly. However, they do not measure chemical parameters directly and the data derived from them should be confirmed by appropriate intrusive investigations, sampling and analysis. Nonetheless, they can prove very useful in the general description/definition of ground conditions and in the focussing of intrusive techniques.

2.3.2 Non intrusive techniques

The principle non intrusive site investigation techniques are discussed in some detail in a report by CIRIA (2002a) and summarised in Table 2.1 below. The Environment Agency also provides guidance regarding the use of non intrusive techniques (Environment Agency 2000c and Environment Agency 2000d).

Table 2.1 Summary of non intrusive techniques

Technique and description	Pros	Cons
Aerial infrared photography: detects differences in reflected energy	Can cover large areas in a small amount of time by using remote controlled model aircraft Can highlight distressed vegetation resulting from contaminated ground or landfill gases	Results can be caused by natural effects such as waterlogging and drought Height of the aircraft can be difficult to judge and can influence the results Flying restrictions may apply
Ground penetrating radar: radar antennae transmits electromagnetic energy in pulse form; the pulses are reflected by the subsurface and then picked up by a receiving antennae	Rapid acquisition of data High resolution of near surface targets Can detect hydrocarbons Helps identify depth to bedrock Detection of non-metallic, metallic non-ferrous and ferrous objects	Poor signal penetration in conductive ground Cannot image beneath groundwater Presence of high conductivity areas such as clay layers can attenuate the electromagnetic energy Only suitable for relatively even ground
Electro magnetometers: based on the effects of ground conductivity on the transmission of electromagnetic energy generated by either natural or man-made sources	Can detect electrically conductive inorganic pollutants and ferrous objects (metal drums, underground storage tanks) Used to identify near-surface water-borne pollution	Presence of high conductivity areas such as clay layers can attenuate the electromagnetic energy Can be affected by 'noise' such as cables and pipes
Electrical resistivity: measurement of apparent resistivity along a linear array of electrodes, to produce an image-contoured 2D cross-section	Can detect electrically conductive inorganic pollutants such as leachate Can be used to differentiate between saturated and unsaturated soils Used to define the location and delineation of the subsurface, for example the base of a landfill site or pathways such as faults Facilitates the acquisition of repeat 'time-lapse' datasets, enabling the monitoring of pollutant migration and the progress of remediation	Contact resistance problems can be encountered in high resistivity ground Very difficult to use on hard standing Coarsening of resolution with increasing depth
Seismic exploration: based on the generation of seismic waves on the ground surface and the measurement of the time taken by the waves to travel from the source, through the rock mass to a series of geophones	Used to define the location and delineation of the subsurface, for example the base of a landfill site or the depth to groundwater Seismic refraction can help identify settlement	Slow production of data Presence of significant ambient noise (e.g. busy road) may inhibit the use of seismic refraction Seismic reflection not well suited for near-surface site investigations

2.3.3 Intrusive investigation techniques

There is a very wide range of intrusive investigations techniques, each of which will have particular properties which will need to be taken into account during selection of the preferred method(s). Typically more than one technique will be used in combination. The various advantages and disadvantages of the commonly used intrusive techniques are summarised in Table 2.2 below.

Table 2.2 Summary of site investigation techniques

Technique	Pros	Cons
Trial pits	Relatively quick easy and low cost to explore ground to 4m depth (or so) Provides good opportunity for visual examination, logging and sampling	Potentially disruptive of site operations/ conditions Reinstatement – can be difficult and costly (e.g. reinstatement of hardstanding) Potential for damage to below ground structures Constrained to above water table working Potential for cross contamination Installation of monitoring instrumentation not recommended
Window samplers	Provides rapid widespread coverage Samples suitable for geotechnical and chemical classification Allows installation of small diameter monitoring instrumentation Limited spoil for disposal. Easy reinstatement	Poor recovery and slow progress in coarse granular materials Relatively small volume samples not always representative Potential for loss of VOCs Installations have limited annular filter pack/ response zone
Shell and auger boreholes	Capable of boring through most soils. Permits undisturbed sampling and *in situ* testing for geotechnical purposes. Larger volume arisings facilitate visual examination, logging and sampling Permits larger diameter installation (50mm pipework inside 150mm filter)	Cobbles etc. inhibit progress and sampling. Not capable of drilling though rock Access can be problematic Drilling can disturb the natural groundwater/ soil gas regimes. Potential for losses of fine grained material and VOCs Potential to create migration pathways
Rotary boreholes	Capable of drilling though solid strata Permits installation (50mm pipework inside 150mm filter)	Core recovery in soft/loose soils poor or requires special techniques. Shell and auger often required to start holes Flush medium can be problematic (e.g. water flush impacts groundwater/air flush can impact soil gas regime/encourage migration of gases/vapours)

2.4 Sampling and analysis planning

Sampling (of soils, waters and gases/vapours) must be taken in accordance with the sampling and analysis plan (Section 2.2.3 above). This should then ensure that all the subsequent samples are representative and of sufficient volume and quality to allow the planned chemical and geotechnical analysis. When designing the sampling and analysis plan, consideration must be given to the type of analysis to be carried out and the use to which the data is to be put. This may influence, for instance, whether disturbed or undisturbed samples are required, or whether spot samples or composite samples are required.

Remember:
When taking samples in the field it is important always to refer back to the Sampling and Analysis Plan to ensure a proper understanding of where, why and what the samples are being taken for.

2.4.1 Sampling of soils

The decision of what soil material should be sampled will be determined by the sampling and analysis plan including consideration of the likely source and likely behaviour of the substances being sampled, as well as site observations regarding the geology and any evidence of contamination.

Representative samples of soils should be taken in accordance with the well defined protocol designed to; minimise cross contamination and loss of volatile compounds etc. and placed in containers appropriate for the subsequent suite of analyses. Samples must be properly labelled (AGS 2000a) immediately in permanent ink and packed in a cold cool box in a manner sufficient to survive transport. The potential for cross contamination can be avoided by the use of appropriate equipment, cleansing materials etc. The recording of the location of where the samples were taken from and their description is critical to the subsequent assessment. Samples should be kept cool and dark and despatched to the laboratory as soon as practicable. If hazardous substances (such as asbestos) are known or suspected to be present or previous investigations have indicated that levels of particular contaminants are very elevated, such information should be passed on to the laboratory to facilitate appropriate handling and sample preparation.

2.4.2 Sampling of surface water and groundwater

Surface water
Samples can be taken from static (lakes/lagoons) or moving water bodies (streams/rivers etc.). There are particular health and safety precautions to be considered in such circumstances. Sampling of surface water is described in detail in BS 6068 (BSI various dates). Meters and probes (e.g. for pH, conductivity, temperature etc.) used at the time of sampling provide useful support data to the laboratory analyses. Sterilised sample containers must be obtained and used from the analytical laboratory (some with appropriate preservatives). The comments regarding sample labelling, packing and transportation given above for soil samples are also pertinent for surface water samples.

Groundwater
The technique/equipment selected to sample groundwater from boreholes will be dependant upon several factors such as:

- The aquifer characteristics (depth to water, permeability etc.);
- The design of the monitoring well (diameter, volume of the well, location of the screened section and pipework);
- The likely nature of the contaminant (i.e. floating product [LNAPL], sinking product [DNAPL] or dissolved phase);
- The monitoring regime (i.e. a single occasion or a programme of visits).

Prior to sampling of newly installed wells, cleaning and development may be required (dependant upon the monitoring programme, the specifics of the hydrogeological regime and the sensitivity of the resulting data). Sampling should not be carried out until the aquifer and the water in the well and gravel pack are in equilibrium (up to 14 days, though this is often not possible). When sampling dissolved contaminants, the sample must be taken only after purging of the well (water standing in a well becomes stagnant affecting its oxidation state and losing volatiles).

Typically, well head parameters should be monitored periodically during purging. Sampling should be undertaken once the parameter readings have stabilised. Alternatively, it is common practice top remove three times well volumes during purging, although there are concerns regarding the suitability of this approach, which is based on an American study. This approach should therefore only be used when monitoring of well head parameters is not practicable.

The potential for sediment to be present in a groundwater sample should be minimised (e.g. using lower flow rates, sample well above base of well etc.). Filtering of samples is best carried out by the laboratory, except where the sample vessel contains a preservative such as an acid. The sampling itself can be carried out by a range of techniques ranging from simple bailers and Waterra check valves through to a number of pumps (from temporary pumps used from the surface to semi permanent installations in the well). The selection of a preferred technique will reflect; the depth to groundwater, volume to be pumped, length and frequency of the monitoring programme etc. The comments regarding sample labelling, packing and transportation given above for soil samples are also pertinent for groundwater samples.

Soil gas
Comments with respect to the sampling of soil gases and vapours are given in Section 2.5.2.

2.4.3 Quality Assurance

Depending upon the particular requirements of any investigation, consideration should be given to the use of “blank” or “duplicate” samples. The objective of such samples is to demonstrate that the sampling and subsequent analysis have been undertaken to an acceptable degree of accuracy and precision. Blank samples include “trip” blanks (prepared by the laboratory before sampling) and “equipment” blanks (prepared in the field with a known solution using standard equipment). “Duplicate” samples are two samples taken from one source, but the identity of the sample point is not given to the laboratory. The duplicate data should be within 20% of each other provided the concentrations are substantially above the detection limit. There will be greater variability when concentrations are closer to the detection limit.

2.4.4 Scheduling of chemical analysis

The scheduling of chemical analyses on samples of soils and waters collected from a programme of site investigation will refer to the Sampling and Analysis Plan (itself informed by the Initial Conceptual Site Model) as well as the observations from the site investigation itself. Therefore the design of the analytical suites will refer to advice on the contaminants anticipated from particular historic and current land uses [from CLR8 (Defra/Environment Agency 2002a) and any relevant DoE Industry Profiles]. However the analyses scheduled must also take account of the sample descriptions and exploratory hole logs to ensure that possible clues to their chemistry (i.e. odour, appearance etc.) are appropriately investigated at the laboratory.

Chemical analyses should be carried out at laboratories appropriately equipped (with staff and resources) and accredited (e.g. by UKAS) to carry out the particular analyses being scheduled. The Environment Agency MCERTS scheme has been devised to provide assurance of the reliability of data from laboratory tests to promote quality and consistency in data from different laboratories. It sets limits for the precision and bias that must be achieved for analysis of particular substances and describes appropriate quality assurance procedures, including the use of reference materials MCERTS accreditation applies to analysis of individual parameters rather than to the laboratory as a whole (Environment Agency 2006b). Chemical analysis should be carried out by laboratories using MCERTS accredited techniques wherever these are available. In order to assist and simplify the process of scheduling chemical analysis, many laboratories have a range of ‘standard’ suites. Whilst this is a useful aide, it is no substitute for interrogation of the data by an environmental chemist and the selection of a suite specific to the site being investigated. Without this degree of scrutiny, it is common to find that; an inappropriate analytical suite has been scheduled, that key determinands have been omitted, or that inappropriately high limits of detection have been agreed etc.

Remember:
It is most important that in scheduling samples of soils and waters for chemical analysis that the analytical suite; responds to the initial conceptual site model, reflects observations on-site and has been determined by, or in consultation with, an appropriately qualified environmental chemist.

On receipt of the analytical data from the laboratory an initial high level review of that data must be carried out. The objective of this review is to determine whether the data set is consistent with field observations etc. or whether it may contain apparent anomalies. For example:

- soils which appeared "oily" were recorded in the field, but the analyses for TPH do not report elevated concentrations of hydrocarbon; or
- analysis of soils where no visual/olfactory evidence of contamination was observed, recorded concentrations of all determinands below "background".

In such circumstances it is essential that the data is double checked with the laboratory. If doubts persist then it is recommended that the suspect sample(s) is/are re-analysed. If this initial review is not carried out, then often by the time a detailed assessment of the analytical data is undertaken, the sample is no longer valid, or may have been disposed off and there is no opportunity for validating the data.

2.4.5 Field test kits

There are a number of analytical tools now available which are suitable for use outside the laboratory (and laboratory controlled conditions). Such field test kits can range from relatively simple screening tools, to sophisticated instruments such as portable gas chromatography machines (see Table 2.3). The Environment Agency has recognised the potential value of such field test kits and a trade association (FASA) has recently been set up to promote their use [www.fieldanalysis.co.uk].

Remember:
It is important that data from field test kits is always supported by sample description and by confirmatory laboratory analytical data as well as an awareness of any specific limitations of the kit.

Table 2.3 **Summary of field test kits**

Technique and description	Pros	Cons
PID (photo ionisation detector) UV light source ionises compounds, causing them to become electrically charged, creating a current that can be measured	Handheld analyser for detection of hazardous compounds in air Interchangeable filter tubes available for specific contaminant detection	Not selective for contaminants other than benzene, methylene chloride or butadiene When used to measure total level of VOCs, cannot distinguish between different compounds. Sensitive to damp weather
FID (flame ionisation detector) Hydrogen flame produces high levels of heat to break bonds of organic compounds, forming positive ions detected by a change in flame conductivity	FID detects flammable gases/vapour. Very sensitive – measurement range as low as 0.1ppm. Results available within 30-75 seconds. Battery pack with 10hours of operation. Reasonably robust. Designed for use outdoors/on-site	Transportation of kit (hydrogen cylinder) problematic. Not intrinsically safe. Not gas type specific and requires oxygen (>13% approx) to record accurately
XRF Based on the effects of ground conductivity on the transmission of electromagnetic energy generated by either natural or man-made sources	Tests soil, air filters and thin film samples. Simultaneous analysis of up to 25 elements Non-destructive chemical analysis. Measurement range from ppm to high % levels Rechargeable batteries allow 8-12 hours of continued use	Radioactive source Expensive piece of equipment Turnaround time per sample: 1-2min
PAH RaPID assays Uses enzyme linked immunosorbant; PAH sample mixed with PAH-enzyme conjugate; magnetic field separates antibodies with bound PAH or PAH-enzyme conjugate; residual conjugate catalyses colour reaction measured by spectrophotometer inversely proportional to PAH concentration	Measures PAHs in soil and water 1-50 samples in 60min	Does not differentiate between different PAHs or other related compounds Water samples must be of neutral pH Soil type can affect the recovery of the contaminant Degree of accuracy can be poor and results often measured in ranges rather than point concentrations.
Portable Gas Chromatograph/ Mass Spectrometer Gas samples pumped into column; soil and water samples loaded into glass vials in an attachable oven, then headspace flushed into machine	Analyses VOCs in air, water and soil Can be operated in Selected Ion Mode and MS-only mode (appropriate for screening activities) Identifies compounds in range of parts per thousand No cool-down time required between sample runs	Machine weighs 16kg. Not readily “site portable”. Expensive piece of kit Only lasts for up to 3hours between recharges Susceptible to interference. Instrument calibration can be a source of error. Results available within 10min

continued >

Table 2.3 Summary of field test kits *continued*

Technique and description	Pros	Cons
Chemical kit – analysis of inorganics Uses self-filling ampoules for photometric analysis of water samples. Colour reaction results from mixing sample with vacuum-sealed reagents pre-packed in ampoule	Range of colorimetric tests available for over 45 analytes Media: water and soil Measurement range: ppm Less than 2min per sample	Each analyte is tested for using a different kit Care must be taken to select test ampoules that will register the appropriate LoD
Chemical kit – analysis of toxicity Measures luminescence change caused by a toxic sample, using naturally occurring luminescent bacteria	Kits available for organics, metals, water-soluble contaminants, hydrocarbons and SVOCs. 22 samples in 75min Test includes presence of unknowns and the effect of contaminant mixtures	Biased towards acutely toxic compounds Test can be affected by pH and coloured extracts Potential ethical concerns
Chemical kit – analysis of TPHs, PAHs and PCBs Uses UV fluorescence where light from a mercury lamp is directed through an excitation filter to irradiate a sample extract	Soil and water samples Can separately measure GROs, EPHs and PCBs Measurement range: from 0.1ppm	Colour quenching can be an issue with very high PAH concentrations Quenching can also occur when testing for a non dominant species
***In situ* probe – analysis of VOCs and SVOCs** Membrane interface probe collects continuous vertical profiles of contamination distribution using gas detectors	Screens for VOCs and SVOCs in soil and groundwater in both free and dissolved phases Up to 80m of probing can be performed daily	Deployed from a Cone Penetration Testing unit, therefore requires use of a drilling rig Relatively expensive Ground conditions can affect performance
***In situ* probe – analysis of petroleum hydrocarbons** Laser pulses light down a fibre optic cable, which causes petroleum hydrocarbons to emit fluorescence	Detects gasoline, jet fuel, lubricating oils, coal tar, creosote, PAHs, BTEX etc. in soil Specially designed to detect heavy-end hydrocarbons More than 90 linear meters of continuous testing per day Concentrations from free-phase to residual concentrations	Deployed from a Cone Penetration Testing unit, therefore requires use of a drilling rig Relatively expensive Ground conditions can affect performance

2.5 Planning monitoring programmes

Monitoring programmes are most commonly employed to record parameters about the surface water, groundwater or soil gas regimes on a site. This reflects the potential for these parameters to vary with time, weather conditions etc.

2.5.1 Water monitoring

The monitoring of groundwater and surface water is essentially a repeat programme of sampling (described in 2.4 above) carried out at pre-determined intervals. Such a programme should specify the duration and frequency of the sampling events within the programme as well as the chemical parameters to be recorded. It is recommended that proposals for groundwater or surface water sampling are discussed with the Environment Agency prior to implementation.

2.5.2 Soil gas and vapours monitoring

The monitoring of soil gas and vapours is described in some detail in a series of recent reports; CIRIA (2007a), NHBC (2007a) and (Wilson et al 2008a). A British Standard was also published at the end of 2007 (BSI 2007a). Advice is given with respect to:

- appropriate monitoring methodologies;
- the design of monitoring programmes;
- available instrumentation;
- the parameters to be recorded;
- the protocol for recording the data obtained;
- the presentation of the data.

Field data should be corroborated by analytical data. Gas sampling and analysis is relatively rapid and will enable confirmation of routine on-site measurements and quantify any hazardous/ odorous trace components. Gas samples can be taken in either pressurised or non pressurised sampling vessels. A well defined sampling protocol will ensure consistent practice and provide confidence in the resulting data (CIRIA 2007a).

2.6 Generic Quantitative Risk Assessment (GQRA)

2.6.1 General

The data obtained from site investigation is then used to refine the initial conceptual site model. The potential pollutant linkages identified in Phase 1 will be confirmed or discounted. Some new pollutant linkages, for which there was no evidence at Phase 1, may also be identified.

For both new and existing housing developments, it is essential to estimate and evaluate both the long and the short-term risks to human heath. For new developments, this will include consideration of risks during construction and post-development. It is also important to consider risks to non human receptors such as surface waters, groundwater, flora and fauna. Developers need to be satisfied that any contaminants in the ground are not likely to damage building materials, services or underground structures. The presence of phytotoxic contaminants (toxic to plants) must be addressed in areas of the development where plants are to be grown, such as gardens and landscaped areas. Some sites may have sensitive ecosystems, such as ponds or woodland, which need to be protected.

Risk estimation is carried out either by using authoritative and scientific generic assessment criteria (e.g. Soil Guideline Values with respect to human health) or by deriving site-specific assessment criteria which are tailored to the particular circumstances of the site. The process of GQRA involves the comparison of the values of contaminant concentrations determined by the investigation of the site (by means of an appropriate sampling and analytical strategy) against relevant generic assessment criteria for the identified contaminants of concern.

2.6.2 GQRA for Human Health

The CLEA model

In 2002 DEFRA and The Environment Agency published technical documents relevant to the assessment of human health risks arising from contaminants in soil. The main Contaminated Land Reports (CLRs) 7-10, described the CLEA (Contaminated Land Exposure Assessment) software and Soil Guideline Values (SGVs) for various substances (see Bibliography). This CLEA software was updated in 2005 with the publication of CLEA UK (beta). These documents are currently the key instruments in the UK for the generic assessment of risks to human health risks from land affected by contamination. Accordingly, in 2002 DEFRA withdrew the DoE ICRCL guidance note 59/83 on contaminated land which had been widely used since 1987.

The CLEA software models the risks to human health from long-term exposure to contaminants, via various pathways, for a range of standard land use scenarios. To date SGVs have been set for nine contaminants – arsenic, cadmium, chromium, lead, nickel, mercury, selenium, phenol, toluene and ethyl-benzene. TOX Reports, providing background toxicological information have been produced for 23 substances (see reference list).

Standard land uses

SGVs have been set for the following land uses:

- Residential homes with or without plant uptake;
- Allotments;
- Commercial/Industrial land use.

Currently there are no SGVs for other common land use scenarios, such as schools, playing fields and public open space etc. Where the conceptual model for a site does not fit with one of these standard land uses, SGVs for a more sensitive use can provide conservative screening values, appropriate for generic assessment. For example, if assessing a playing field land use, SGVs for residential use without plant uptake will provide a conservative screening value, whereas SGVs for commercial/industrial land use would not. Failure against conservative screening values indicates a need to carry out a Detailed Quantitative Risk Assessment (see Section 2.7) or some other form of risk mitigation.

Routes to exposure

SGVs are also dependant on a number of assumptions, for example relating to soil conditions (pH and organic carbon content), the behaviour and type of pollutants and the availability of receptors. The CLEA model allows consideration of the following pathways:

Outdoor inhalation of soil vapour	Indoor inhalation of soil vapour
Outdoor ingestion of soil	Indoor ingestion of dust
Skin contact with outdoor soil	Skin contact with indoor dust
Outdoor inhalation of fugitive dust	Indoor inhalation of dust
Consumption of homegrown vegetables	Ingestion of soil attached to vegetables.

Consideration may also need to be given to other exposure routes which may be present on a development site. Many developments will incorporate barriers to exposure independent of any assessment of contamination, for example, areas of hardstanding provided for car parking. The presence of such features should be duly reflected in the consideration of exposure pathways and incorporated in the risk assessment.

Statistical assessment

The value of a contaminant concentration which is considered representative of the contamination on the site (or part of a site) must be derived from the statistical analysis of the chemical analytical data obtained from the investigation (Defra/Environment Agency 2002c (CLR7)). Recently guidance was developed (CIEH/CL:AIRE 2008a) to improve the general statistical approach and to support new Defra policy in this area in accordance with the “Way Forward” consultative document (Defra 2006c).

The previous guidance (Defra/Environment Agency 2002c) indicates that the mean value test should be used to compare a representative mean of the data (upper confidence limit of the mean, the US_{95} value) against the SGV. The US_{95} is a calculated value below which the actual average soil concentration will be 19 times out of 20 (i.e. 95% of the time). In other words, comparison of the US_{95} value against relevant assessment criteria can provide a reasonable degree of confidence that the actual average concentration of contaminant on the site is below (or above) that criterion.

Consideration must also be given to the relevant averaging area and to the most appropriate method of grouping the data, both of which **must relate to the conceptual model**. For instance, the data can be grouped spatially (i.e. for individual zones within a site) or by particular strata. The required approach may vary for different contaminants, as some may be associated with specific current or historical activities carried out in a particular location while others may be associated with materials (such as made ground) brought on to level the site.

Example:
For a site where chromium contamination is associated with a particular type of fill material, division and characterisation of data by the various types of Made Ground may be appropriate. Conversely, on the site of a former plating works, where soil contamination is associated with former chromium plating tanks, spatial division of data would be required.

Where individual, or a small number of samples contain much higher or lower concentrations than the rest of the dataset, statistical tests should be used to determine whether or not those unusual data form part of the same statistical distribution. The maximum value test is recommended to determine statistical outliers (Defra/Environment Agency 2002c) but other statistical methods (e.g. Rosner's test and the Q test) can also be appropriate. [Note: CIEH and CL:AIRE are currently preparing further guidance/advice on statistical treatment of data.] If statistical outliers are identified, this should lead to a review of the data. Such a review should critically examine:

- The potential for error introduced by sampling;
- The validity of the chemical analytical results;
- The potential on-site source;
- The description of the soil sample (e.g. on the trial pit log).

This will assist in determining the treatment of the outlier in the subsequent risk assessment.

Remember:
Statistical outliers should never be ignored or summarily dismissed as "errors" or "anomalies".

Comparison of data against SGVs
When the US_{95} values of contaminants fall below the appropriate SGV, those particular contaminants and/or the areas of the site for which they are representative, can be considered not to pose unacceptable risks to human health. Where concentrations of contaminants exceed the SGV, the presumption is that there is sufficient evidence for *potentially* unacceptable risk to human health to warrant further consideration. This further consideration might be investigation to establish, on the basis of more detailed data, whether there is an unacceptable risk, or to proceed to the implementation of remediation action. In a contaminated land advice note (Defra 2005a) guidance was issued which:

- confirmed that in order to determine a site as "Contaminated Land" under Part 2A of the EPA 1990 there has to be "significant possibility of significant harm" (SPOSH); and
- stated that SGVs mark the concentration of a substance in soil below which human exposure can be considered to represent a "tolerable" or "minimal" level of risk.

On this basis DEFRA went on to say that concentrations of substances in soil equal to, or not significantly greater than, an SGV would not necessarily satisfy the legal test of representing a "significant possibility of significant harm". In 2006, in its Way Forward document (Defra 2006c), DEFRA consulted on possible and technical options for resolving this and other areas of uncertainty. To date final, guidance has not been published.

Other UK Generic Assessment Criteria

Many consultants have developed their own generic assessment criteria (GACs) incorporating UK policy conditions with some using the CLEA model and others using alternative models for determinands for which there are no published SGVs. In 2007, a series of GACs were derived and published (CIEH/LQM 2007a) using the CLEA model beta version for 31 determinands for the four standard scenarios. The resulting published report also included full details of toxicological source information etc. These criteria may be considered suitable as a primary screening tool for the assessment of minimal risk levels. However, all of these various GACs must be used with some caution as they have not been formally reviewed or endorsed by Government or the Environment or Health Protection Agencies.

Cautionary note on the use of International Generic Assessment Criteria

International generic guideline values may also be of use as decision support tools when assessing a new contaminant, although such "guidelines" have no regulatory standing in the UK. Such guidance may have been developed in accordance with policy decisions which are different to the UK and therefore these guideline values can be difficult to modify to be compliant with the UK context. The guidance often refers to a standard soil with particular properties and therefore adjustments to the values may need to be made for UK soils. Associated detailed reviews of chemicals including the toxicological data may assist in a detailed risk assessment. Risk assessors must always be aware of the basis for these various international threshold values to ensure their applicability in the UK context and that the EA preferred approach in the absence of published SGVs is to move to a Detailed Quantitative Risk Assessment and the derivation of site specific criteria via CLEA.

Remember:

1. Government endorsed Soil Guideline Values (SGVs) currently exist for nine contaminants although toxicological background data has been produced to enable production of guideline values for a total of 23 substances (including the nine with SGVs).
2. Care should be taken when using guidelines values derived by others, especially without consideration of UK policy, and supporting evidence on their background should be provided.
3. Exceedance of an SGV does not necessarily mean that there is an unacceptable risk to human health but that further consideration is required.

Radioactivity

Threshold values at which radioactive substances come under statutory control with reference to UK legislation are defined in the Radioactive Substances Act 1993. The interaction between radiation and Part 2A is defined in the Statutory Guidance (Defra 2006a) which defines the criteria above which the local authority should regard harm as being caused. The "Radioactively Contaminated Land Exposure Assessment Methodology" (RCLEA) is Defra's recommended approach for GQRA related to land affected by radiological contamination. It applies to long-term radiation exposure situations and complements the CLEA model for non radioactive contaminants. The methodology is based on a set of mathematical models and data that calculate radiation doses from radionuclides in the soil (Defra 2006d, 2006e, 2006f).

Explosives

There are no UK generic guidelines for levels of explosives in soil but the Environment Agency have produced research reports on the toxicity and fate/transport of selected explosive compounds (EA 2000c). The US Environmental Protection Agency in Region 3 has carried out generic risk assessment to establish acceptable levels of these contaminants based on their toxic effects www.epa.gov/region03.

Asbestos

There are no UK generic guidelines related to the presence of asbestos in soils.

2.6.3 GQRA and controlled waters

Information on groundwater quality at a site is obtained directly from sampling and chemical analysis of groundwater within wells installed in boreholes and indirectly from leaching tests (which are largely restricted to metals). Leaching tests on soil samples are also important, particularly when soil/made ground has previously been protected from leaching by the presence of buildings or hardstanding.

Guidance is provided in CLR1 on estimating and evaluating risks to groundwater and surface water (Department of the Environment 1994c). This provides a framework for assessing the impact of contaminated land on groundwater and surface water. The Environment Agency has developed a tiered methodology (Environment Agency 2006c) to derive remedial targets for soil and groundwater to protect water resources. Although primarily aimed at deriving remedial targets for site remediation, the methodology also predicts the impact on water receptors for a given set of site conditions and so can also be used to determine whether remedial action is required.

Risks to water quality are largely related to the toxicity and mobility or leachability of soil contaminants rather than just the total contaminant concentration. The first tier of the assessment (Tier 1) is carried out by comparing measures or estimates of the concentration of contaminants in the soil pore water (e.g. from leachability tests) with the guidelines acceptable in the target water resources. The initial Tier 1 assessment is thus used as a screen to determine which, if any, of the soil contaminants could potentially pose a threat to water resources. [Tier 2 and Tier 3 assessments are carried out at the Detailed Quantitative Risk Assessment stage – see Section 2.7.]

The Environment Agency has published advice to third parties on the pollution of controlled waters with respect to Part 2A (Environment Agency 2002d) and has revised guidance on the assessment of contaminant leachability (Environment Agency 2006c). The results of these analyses should be compared with relevant water quality standards, which may also include background water quality. The Drinking Water Standards (OPSI 2000a) should be used for initial comparison, although care in their use is needed as they are only strictly applicable to water intended for human consumption. Chemical analysis results can also be compared to Environmental Quality Standards (EQS) for fresh and salt waters as derived from the EC Dangerous Substances Directive (Ref 76/464/EEC). EQSs are given as annual average figures and they indicate the concentration of the specific substance that is protective of aquatic life, which are typically aquatic invertebrates or fish. Some EQSs vary with water hardness and so this parameter must be included in the analytical suite. The Environment Agency is currently drafting further guidance on the assessment of TPH data (Environment Agency in preparation) and on the setting of remedial targets.

As with the soil standards, international generic assessment criteria for protection of groundwater may also be considered in GQRA. However, caution must be adopted if they are referred to as they have no regulatory status in the UK.

2.6.4 GQRA and the built environment

Various contaminants can represent a risk to buildings and structures, for example through an explosive risk (e.g. methane) or by material degradation (e.g. sulphate attack on below ground concrete). Useful guidance on the assessment and management of risks to buildings, building materials and services from land affected by contamination has been published by the Environment Agency (Environment Agency 2000d).

Generic guidance in relation to assessing risks to buildings from soil gas is included in a number of publications. Assessment concentrations relating to the components of landfill gas are given in Waste Management paper 27 (Department of the Environment 1991a) and Approved Document C in relation to the Buildings Regulations (ODPM 2004b and OPSI 2000a). Detailed guidance on investigation, risk assessment and development of gas contaminated land has been published by CIRIA (2007a); NHBC (2007a); CIEH (2008a) Wilson & Card (1999a); British Standards (BSI 2007a) and the BRE (1991a and 2001a). The approach in all of this recent guidance is based on the calculation of a Gas Screening Value (GSV). The GSV is calculated by multiplying the gas concentration (% v/v) by the borehole flow rate for each borehole (l/hr). The GSV can then be compared against derived thresholds to define the "Characteristic Situation" for the site (CIRIA 2007a) or a "traffic light" colour code (NHBC 2007a) which in turn informs the risk assessment and the need for and scope of remediation action.

Approved Document C (ODPM 2004b) also considers the types of contaminants that may be left *in situ* beneath building footprints and requires the treatment by removal, filling or sealing of oil and tarry materials, corrosive liquids and combustible materials beneath proposed buildings. Where high levels of contamination are found, removal is often the only viable option as contaminants can migrate if/when the groundwater regime is influenced by the development. Approved Document C recommends that in such circumstances, specialist advice is sought and that the local authority environmental health officer is consulted.

Sulphate can adversely affect buried concrete structures by sulphate attack. Measurements of sulphate and pH can be made to allow assessment and appropriate classification based on guidance from the Building Research Establishment (BRE 1994a).

Currently, the various water companies refer to different standards when assessing the potential risks to water supply pipework. A number rely on guidance published by the water supply industry body, WRAS (2002a). However, the derivation of the various thresholds in that guidance is not clear and is not risk based. More recent guidance (UKWIR 2004a) has proposed that the assessment of the hazard to water pipes should based on consideration of the three pathways for exposure of the pipework to ground contamination, namely: contact with migrating groundwater, permeation of vapour and direct contact with soils.

2.6.5 GQRA and ecological systems

Assessment criteria for risks to ecological systems are currently less well developed than those for human health and water quality. The Environment Agency in conjunction with others including Natural England, the Countryside Council for Wales and Scottish Natural Heritage is developing a framework for ecological risk assessment which is supported by Government. This framework is being developed to support decisions regarding risk to eco-receptors from contaminated land under Part 2A and was subject to public consultation (Environment Agency 2004a). The major ecological drivers which are increasingly underpinning legislation and policy are looking to maintain (if already in good or appropriate condition) or otherwise enhance or restore ecological receptors. Therefore, achieving an Environmental Quality Standard (EQS) for an aquatic environment may not be good enough if that allows the existing quality of the environment to deteriorate. For example under the Water Framework Directive (WFD) the default is "Good Ecological Status" and only very prescribed exceptions will be allowed to fall below this standard. Under the WFD the prescriptions do not only relate to water quality but include quantity, geomorphological and aquatic biological regimes and these, together with water quality, are all surrogates for measuring/assessing the condition of aquatic habitat.

This approach is not confined to the WFD. Planning policy guidance (DCLG 2005a) and the latest PAS2010 (BSI 2006a) (a British Standard code of practice which aims to effectively manage/protect biodiversity in planning) also reflect this philosophy. Assessment of the risks to aquatic fauna as a result of deterioration in water quality can be made by comparison against Environmental Quality Standards (EQS), but this does not address risks posed by changes or removal of habitat. Consideration needs to be given to the effect of development on protected species (for example badgers, bats and Great Crested Newts), designated areas of nature or ecological importance (such as Sites of Special Scientific Interest) and the wider environment (such as the protection of trees, hedgerows and other flora and fauna). Advice on these issues may be obtained from Natural England, the Countryside Council for Wales and Scottish Natural Heritage or from local nature conservation groups. Dutch Intervention Values (DIV) for some compounds are based on ecotoxicological risk rather than human health and therefore may be appropriate for comparative purposes for particular ecological receptors.

2.7 Detailed Quantitative Risk Assessment (DQRA)

2.7.1 General

In some instances generic guideline criteria are either unsuitable, unavailable or exceeded. In these cases it will be necessary either to use other generic criteria or to calculate site specific assessment criteria, based on toxicity data and calculated exposure. A specialist risk assessor will almost certainly be needed to undertake the work, which should be based upon the comprehensive risk assessment guidance provided in the Model Procedures (Defra/Environment Agency 2004a). Developers should note that while generic criteria or models developed in other countries, for example the Netherlands or the USA, could potentially be appropriate, it is essential to critically examine the assumptions built into the criteria or models and determine if they are applicable to the site conditions and to the UK policy and good practice (see the discussion above in Section 2.6.2).

The regulatory authorities will need to be satisfied with the site-specific criteria proposed and the approach used in its derivation. The risk assessor should therefore produce a documented assessment which can be evaluated by the regulator, who will be looking for transparency in deriving values, evidence of sound science and clarity in any assumptions made. Annex 5 includes guidance on choosing appropriate site specific risk assessment models and the data requirements for such models. It also includes a précis of currently available risk assessment models. Issues for consideration when undertaking DQRA with respect to human health and controlled waters are described below.

2.7.2 DQRA and human health

In many cases the CLEA guideline values (SGVs) or other comparable generic screening values will be appropriate to estimate the long-term risks to human health that may be associated with new or existing housing developments. However, where there is concern about risks to humans already living on a site, for example, because an SGV has been exceeded, it may be necessary to establish site-specific criteria for use in DQRA. Contaminants for which TOX reports do not exist will need a toxicity review which could be several days work by a toxicologist.

When deriving a guideline value for a substance for which there is no TOX report, reference should be made to the approach outlined in CLR9 (Environment Agency 2002b). This prioritises various data sources, starting with authoritative bodies in the UK, then European Commission committees and international authoritative bodies (such as the World Health Organisation), then other national organisations and finally “authoritative bodies but for different purposes”. The Health Protection Agency (HPA) is currently drafting clarification notes and toxicological compendia for various determinands which, when available, will assist in this process. Some of the international thresholds are based upon toxicological data and this data may assist in a DQRA. However, as described for GQRA, care must be taken when using any such data to ensure that is relevant to (or can be adjusted to) UK conditions.

Detailed site specific criteria may also be required where the conceptual site model differs from that in the standard land uses. This might involve changes to one or more parts of the conceptual model, such as:

- To the receptor (e.g. changes to exposure times or the ages of the receptor might be required when considering users of a recreation area at an adult prison or a playing field at a school);
- To the pathway (e.g. changes to dermal contact at a sports field, or differences in building characteristics and depths of contamination for a volatile contaminants, or introduction of a new pathway such as eating fruit from trees on-site or swimming in a lake or removal of a pathway (e.g. the area is completely covered with hardstanding but volatile contaminants may get into buildings or outdoor air); or
- To the source (e.g. a combination of contaminants may have additive effects, synergistic (more than additive) effects or antagonistic effects – further details on looking at additive effects are provided in CLR9 (Environment Agency 2002b) and Environment Agency (2005a).

Many generic guideline values are not fixed for each defined land use, but vary according to soil characteristics. For example, soil organic matter affects benzo(a)pyrene by binding it to the soil so that its potential for mobilisation is reduced. It is therefore important to analyse for soil organic matter when assessing risks from organic compounds such as B(a)P. Soil pH also has an effect on the mobility of many contaminants. Thus, an appropriate guideline value must be derived by taking such factors into account (Environment Agency 2002c, updated version of CLR10 anticipated 2008).

Bioavailability and bioaccessibility
Bioavailability refers to the amount of contaminant from soil taken up by the body (i.e. enters bodily fluids). Bioaccessibility relates to the laboratory estimate of the fraction of a substance that is soluble in the gastrointestinal tract and therefore available for absorption (Environment Agency 2007a). There has been very little validation of bioaccessibility techniques with actual data on humans or animals. Bioaccessibility data using a physiologically based technique can be used to inform the risk assessment and adjust the uptake via a particular pathway. However, its limitations should be borne in mind and it should not be used on its own without other supporting evidence, e.g. geochemical information. The limitations/uncertainties of bioaccessibility data have been well documented by the Environment Agency (2005b and 2007a). A working group set up by CL:AIRE in 2007, is currently developing a framework aiming to assist in the use and interpretation of bioaccessibility data. The CIEH is currently sponsoring the preparation of guidance for regulators. A draft ISO on the application of methods for the assessment of bioavailability is also currently being developed (British Standards 2008a).

2.7.3 Controlled waters

If leachability test results exceed relevant generic environmental standards then more detailed assessment of the fate and transport of contaminants in the subsurface may be undertaken using the following guidance. Further stages in the methodology for deriving remedial targets consider dilution of infiltrating water in the aquifer (Tier 2) and then more complex processes such as attenuation or degradation are incorporated in Tiers 3 and 4 [Environment Agency 2006c] and ConsimV2 [www.consim.co.uk]. These assessments require substantially more data than a generic (Tier 1) assessment.

In deriving site-specific assessment criteria for pollution of controlled waters it is important to consider the requirements of EU and UK legislation. In particular the Groundwater Directive (Ref 80/68/EEC 1979a) requires that List I substances are prevented from entering groundwater and entry of List II substances is minimised to prevent pollution of groundwater. It should be noted that the Groundwater Directive will be replaced by the Groundwater Daughter Directive within the Water Framework Directive (WFD). There are already a small number of substances (e.g. nitrates and pesticides) within the WFD for which minimum standards are already in place. Similar requirements relating to surface water bodies are made under the Dangerous Substances Directive.

Natural (background) water quality should be protected and land remediated to a standard that ensures this. However, this may not be appropriate and in all circumstances cost/benefit should be considered when assessing the need for and type of remediation to be undertaken. The environment agencies hold and publish water quality monitoring data that may be used for assessment purposes. Water quality information is also included in a number of documents published by the drinking water inspectorate www.dwi.gov.uk.

2.8 Risk evaluation

The purpose of risk evaluation is to establish whether there is a need for risk management action. This involves the collation and review of all information relating to the site in order to:

- Address areas of uncertainty and their possible effect on risk estimates;
- Identify risks that are considered unacceptable in both the short and long-term;
- Set provisional risk management objectives for addressing the unacceptable risks.

2.8.1 Risk estimation from short-term exposure [Acute risk]

In some cases there may be risks to human health from short-term exposure to contaminants, for example from direct contact with temporary stockpiles of excavated material or where contaminants at depth have been exposed. Such risks may occur when construction work re-exposes contaminants or excavation releases volatiles or generates dust. Similar risks may occur on existing development where maintenance, repair or refurbishment may involve excavation of the ground. Where such potential risks are identified, exposure will initially be to the developer's workforce and therefore, risk mitigation measures should be described in appropriate health and safety advice. Evaluation of any such acute risks should be combined with the evaluation of long-term risks to human health and other receptors as described in Sections 2.6 and 2.7.

There are currently no UK guideline values for assessing acute risks from soil contamination, although occupational exposure limits have been set for exposure to contaminants in vapour and dusts (HSE 2005a). Where separate short-term effects from exposure to contamination are known, it may be advisable to consider a one off high soil ingestion rate, when deriving site specific assessment criteria (Environment Agency 2002c). Consideration should also be given to maximum concentrations rather than US_{95} values etc. When considering one off movements of vapours, controls on nearby personnel and monitoring may be more appropriate. A conservative approach to substances that could pose acute risks and where there is no recognised standard, would be to move directly to remediation action, rather than to try to derive a standard.

2.8.2 Components of development

Different components of a residential development, for example homes with gardens or flats with common areas, may have different sensitivities to contamination, based on an assessment of the risks with each component. Components of residential development might include:

- The dwelling unit as an entity (taking into account various structural options which may be employed, for example ground bearing slab, suspended floor) where exposure of receptors to certain contaminants is not influenced by associated external areas such as gardens;
- The dwelling unit in combination with
  - i. a private garden
  - ii. a communal garden
  - iii. a hard landscaped area;
- a private garden comprising soft landscaping;
- a communal garden/common areas comprising soft landscaping;
- hard landscaping.

There are a number of possible exposure scenarios which may occur if pathways are created following completion and occupation of a development. Penetration of cover materials due to excavation can occur, for example in the case of extensions, swimming pools, ornamental planting or drainage maintenance and construction. This may result in temporary surface stockpiling and longer term disposal of materials by spreading at ground level. Occupants of the dwelling, particularly very young children playing in gardens and communal areas and consumers of vegetables grown on the property, could be subject to accidental or uncontrolled exposure to the contaminant. Infiltration of site drainage by contaminated surface water or groundwater may adversely impact the quality of receiving waters or aquatic systems.

2.8.3 Identification of unacceptable risks

The identification of potentially unacceptable risks therefore commences with a comparison of the measured concentrations of contaminants in the soil (derived from the results of site investigation) with relevant generic or site specific assessment criteria. Risk evaluation involves the collation and review of this information in the context of the proposed development and its detailed components. It must involve qualification of the significance of this information with reference to the associated technical uncertainties, and especially the degree of confidence in the accuracy and sufficiency of the data produced, and consideration as to whether the assumptions used in the risk estimation are likely to have over or underestimated the risk. If the results of the above comparisons are marginal, the risk assessor may:

i. seek to obtain more data to refine the risk estimates;
ii. adopt a precautionary approach which assumes that the risks involved are unacceptable.

Often a cost/benefit analysis of these two options will inform the selection of the subsequent action. For example, on a site where slightly elevated gas concentrations have been found, rather than undertake an extensive monitoring programme it may be decided to adopt a precautionary design (i.e. install gas protection measures), thus saving time in the overall construction programme. The nature of the risk also needs to be taken into account. For example, if on a site, phytotoxic metals are recorded at concentrations marginally above relevant criteria, the financial and environmental consequences are relatively small and easily corrected, compared to the potential risks associated with elevated concentrations of landfill gases, together with the difficulties of retro-fitting gas protection measures.

Remember:
It is also important at this stage to take proper account of risk perception issues as this must be considered in both the identification of unacceptable risks and also in the setting of remediation objectives. Some more detailed information of risk perception and communication issues is presented in Annex 6.

2.9 Waste management

Development of brownfield sites often involves the production, handling and disposal of excess soil arisings as “waste”. Typical wastes include demolition materials and soils (including Made Ground) which may or may not be contaminated. Appropriate classification (and often pre-treatment) of waste is required prior to either re-use on-site or off-site disposal. Duty of Care associated with handling waste can have time and cost implications for the developer.

The definition and classification of waste are complex issues and must be fully understood at both this site investigation stage (where consideration of waste will influence the design of the site investigation, the sampling and analysis plan etc.) but also during remediation and site redevelopment (see Section 3). A summary of the waste management aspects of the development of land affected by contamination are provided in Annex 7.

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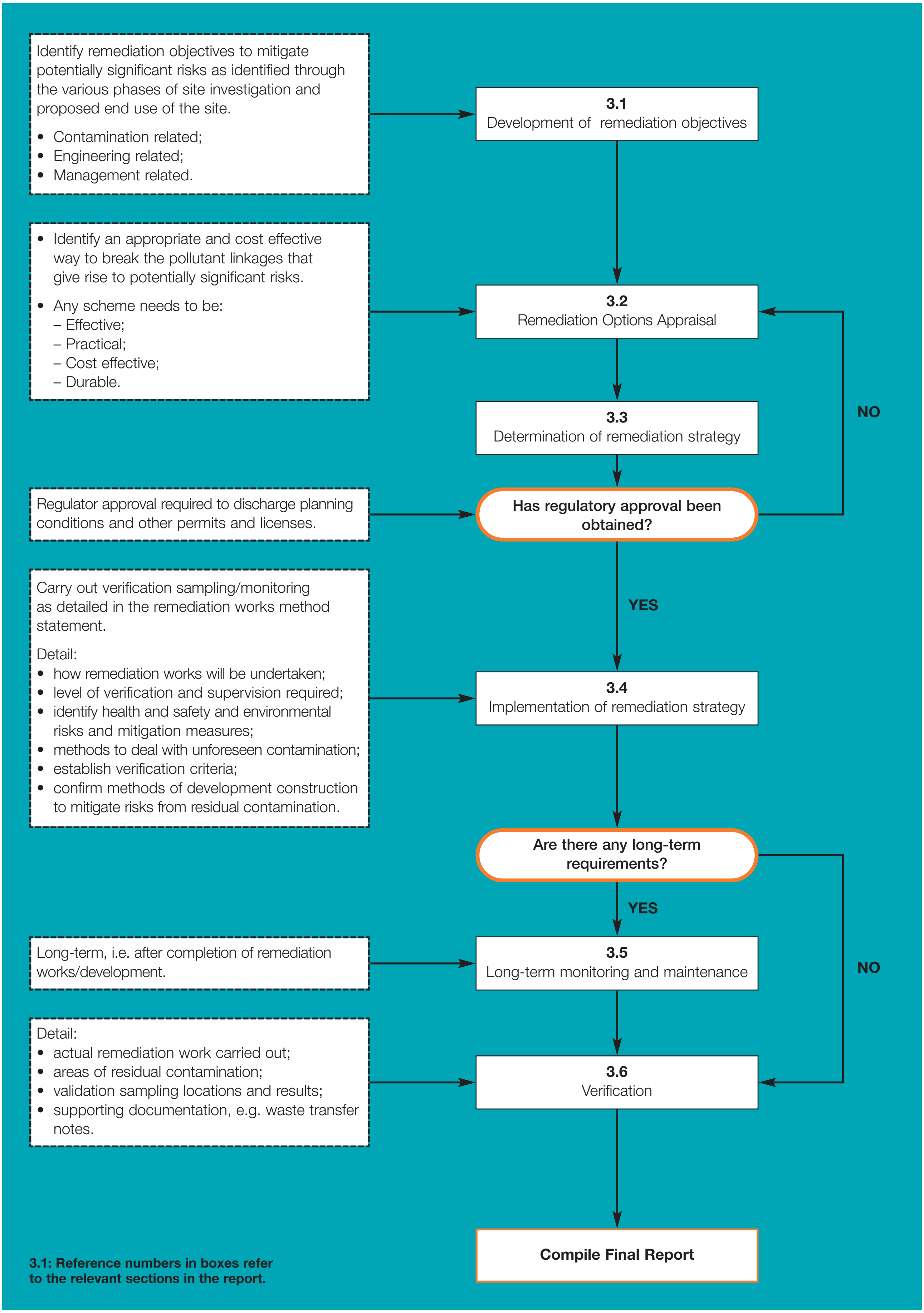
Chart 3 **Phase 3:** Remediation; design, implementation and verification



Phase 3
Remediation; design, implementation and verification

3.1 Objectives

3.1.1 General

The overall aim of the work in Phase 3 is to design, implement and verify the remediation works necessary to mitigate the potentially unacceptable risks identified in Phase 2. The remediation process therefore begins with development of the remediation objectives and the options appraisal process. It progresses by means of various remediation activities including verification as illustrated in Chart 3 [and by the Case Study, Chart 3A in Volume 2].

The process of remediation design, implementation and verification thus comprises:

- Definition of remediation objectives [Sections 3.1.2 to 3.1.5];
- Appraisal of the options for remediation and selection of a preferred strategy [Sections 3.2 and 3.3];
- Planning and implementation of the remediation strategy];
- Long-term monitoring and maintenance [Section 3.5];
- Preparation of Verification Report [Section 3.6].

The conceptual site model, refined from the results of the site investigation, will play a crucial role in the identification of the remediation options and the eventual selection of a preferred remediation scheme. During the remediation itself, it is very likely that additional data will be obtained requiring further refinement of the conceptual model.

In 2008 the Environment Agency published a consultation draft of Guidance on Verification (Environment Agency 2008a) which emphasised:

- The need to plan verification as in integral part of remediation; and
- The importance of the conceptual model and the development of multiple lines of evidence.

Remember:
All relevant data including the final description of the conceptual site model must be captured in the Verification Report.

3.1.2 Setting objectives

The risk assessment(s) carried out at the conclusion of the Phase 2 works will have identified all potentially unacceptable risks. The remediation objectives must manage the risks associated with each pollutant linkage identified in the conceptual model. On many sites, a range of objectives may be established in response to the different nature of the risks associated with different pollutant linkages. For example, on a site containing fill material consisting largely of degradable waste material with associated unacceptable risks, the associated preliminary remediation objectives could be summarised as set out in Table 3.1.

Table 3.1 Example summary of preliminary remediation objectives

Unacceptable risks	Preliminary remediation objectives
Damage to plants from phytotoxic heavy metals	Prevention of contact between contaminated soil and the root zone in planted areas
Explosion caused by methane ingress into buildings	Prevention of methane migration into areas close to the buildings
Human health effects through direct contact with soil	Prevention of contact between contaminated soil and humans in gardens, play areas and public open spaces
Pollution of groundwater by substances leached out of the fill	Reduction of leaching from contaminated soil by preventing water infiltration

In addition to the remediation objectives, legal obligations will also exist. A wider consideration of the circumstances of the land and its management context must also inform the remedial process. For example, there will be site specific particulars about the development itself (i.e. its layout and likely methods of construction) as well as requirements and/or aspirations of the Regulators (and other possible stakeholders). Some examples of such circumstances are set out in Table 3.2).

Table 3.2 Examples of site specific constraints

Type of circumstance	Typical issues
Commercial	Time, cost and extent of liabilities.
Legal	Need to meet certain conditions or to obtain license/permits. Need to manage any civil and criminal liabilities.
Physical	Location, size, current use, access to the site and boundary issues.
Engineering	Need to engineer the ground to ensure safe construction and/or to protect existing buildings.
Other	Need to ensure suitable amenities/other facilities, for example, provision of suitable gardens as part of an existing or future development. Public perception.

Typically remediation objectives are considered in one of three groups:

1. Contamination related;
2. Engineering related; and
3. Management related.

These objectives are described in turn below.

3.1.3 Contamination related objectives

Contamination remediation objectives must be based on the conceptual model for the site and must define the desired end condition. They can be qualitative or quantitative but must always relate to the risk assessment. Contamination related objectives are the most important of the three (types of objectives) and wherever possible should drive the selection of a remediation option. Examples of contamination related objectives are given below:

- Qualitative
  i. The remediated site must be suitable for occupation by people in homes with private gardens.
  ii. All below ground fuel tanks and associated hydrocarbon contamination must be removed from site.
- Quantitative
  i. The average (US_{95}) residual concentration of lead in the topsoils and subsoils on-site (within 1m of the ground surface) after remediation must not exceed 450mg/kg.
  ii. The maximum concentration of polyaromatic hydrocarbons [the sum of benzo(b)flouranthene, benzo(k)flouranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene] in any of the observation wells shall not exceed 0.1ug/l.

3.1.4 Engineering related objectives

The improvement, maintenance or modification of the engineering properties of the physical ground conditions on a site are commonly an important aspect of a remediation project. Improvements in stability of the site or changes in ground levels may be required in order to construct the proposed development. There may be a need to overcome conflicts between a favoured remediation technique which deals with contamination and the engineering objectives of the project. For example, lime stabilisation may reduce mobility of some contaminants but it will also change the soil properties. Changes to soil properties can be either negative, for example some stabilisation techniques can increase the soil pH causing aggressive soil conditions for buried concrete; or positive, such as improving bearing capacity. In any development project it is important that the construction process does not create new pathways by which contamination may migrate (e.g. by piles driven through contaminated Made Ground and a low permeability clay into underlying sands and gravels – a sensitive aquifer). Other ground improvement techniques can also have un-wanted effects on contamination (e.g. dynamic compaction can encourage off-site migration of ground gas). Examples of engineering related objectives are given below:

- The remediated soil must have a bearing capacity and settlement characteristics sufficient to support a two storey building.
- The clay capping must have a CBR value of not less than 5%.

3.1.5 Management related objectives

Management related objectives often relate to aspects of the remediation process itself, but also to the site after remediation has been completed. For example, the costs of a particular remediation option may exceed the budget, making the development not financially viable. Programme constraints may conflict with the use of a particular remediation technology (or technologies). On sites where there are existing buildings or structures to be retained, or where existing activities are to continue, remediation activities will have to be designed and carried out to avoid unnecessary disruption. A common objective on development sites is that on completion of the development (i.e. occupation by the homeowner) there will be no requirement for any further monitoring. Examples of management related objectives are given below:

- The houses on the development need to be ready for occupation by the end of the Financial Year.
- Groundwater treatment wells and pipework must not impede below ground works/piling etc.

Remember:
It is crucial that remediation objectives are defined at the start of the process and that all objectives are considered. If they are incorrect or incomplete then the remediation scheme will not be effective or efficient. This process should be clearly documented. Objectives are contamination, engineering or management related.

3.1.6 Measurement of objectives

Once the remediation objectives have been defined, remediation criteria specific to the site and to the defined objectives need to be identified. The remediation criteria provide the measures against which compliance with remediation objectives will be assessed during and after the implementation of the remediation strategy. For example:

- How will the remediation objective be measured?
  [For example; the outcome of an *ex situ* bioremediation scheme may be a **measured reduction** in the concentration of the contamination in the soil heap. For a cover system, the properties of the capping in terms of its thickness and engineered properties are more appropriate than measuring contaminant concentration beneath it.]
- Where is the remediation objective to be measured?
  [For example; the media type, location of samples, and extent of area/volume to be covered.]
- When will the objective be measured?
  [For example; periodic measurement of contaminant concentrations during bioremediation.]

3.2 Remediation options appraisal

3.2.1 The options appraisal process

Having identified the remediation objectives, an appraisal of potentially suitable remediation options must be carried out. Conceptually, remediation action will involve breaking the pollutant linkage or linkages by use of one or more of the following methods:

- source control: technical action either to remove or in some way modify the source(s) of the contamination. Examples might include excavation and removal, bioremediation or soil venting;
- pathway control: technical action to reduce the ability of the contaminant source to pose a threat to receptors by inhibiting or controlling the pathway. Examples would include the use of engineered cover systems over contaminants left *in situ* or the use of membranes to prevent gas ingress into buildings;
- receptor control: non-technical actions or controls that alter the likelihood of receptors coming into contact with the contaminants, for example altering the site layout.

A wide range of different techniques can be used individually or in combination to achieve a break in a pollutant linkage. The options appraisal will consider a technique's effectiveness in dealing with the contaminants of concern, but will also give consideration of the wider circumstances of the site (Table 3.2).

Short listing of the potential remediation options should take account of the available information and any associated uncertainties. For example, a technique may be initially identified as potentially suitable on the basis of its general effectiveness, but later, more site-specific evaluation may eventually lead to it being discounted. The short listed options will then be subject to detailed analysis to consider the advantages and disadvantages of each approach.

The analysis will have to balance a range of issues taking account of the wider circumstances of the site and any specific requirements of the remediation objectives. The analysis should be as comprehensive as possible, necessitating the collection of additional information as appropriate. The range of issues to be considered includes:

- costs and benefits (including finance considerations and liability);
- effectiveness of meeting remediation objectives (including site-specific criteria, timeliness, durability, risk-based and non risk-based objectives);
- wider environmental effects (including disruption to amenity, emissions, sustainability);
- regulatory requirements (meeting certain conditions or obtaining a licence or permit);
- practical operational issues (for example, site access, availability of services, agreed access); and
- aftercare issues (for example, the need to maintain and inspect remediation systems or to establish longer term groundwater or gas monitoring).

The selection of evaluation criteria is a site specific matter although many criteria will be common to many sites and techniques. This assessment may be carried out on a simple qualitative basis or may involve more detailed semi-quantitative assessment (an example of which is given in Table 3.3 overleaf). In either case it is advisable that some prioritisation or weighting is applied to these different factors, so that the most relevant, balanced assessment can be made. It may be worth investing more time and resources in this selection process where the choices to be made are particularly difficult, for example if a wide range of different stakeholders is involved.

However, it is very important that the process is carefully documented with a high degree of clarity and transparency, to enable the selection of the final strategy to be explained to the different stakeholders, such as the general public, company shareholders, local authority (Planning and Environmental Health Departments as well as Contaminated Land Officers) and the Environment Agency. Further information on this selection process can be found in the Model Procedures (Environment Agency 2001a) and an example of the quantitative approach is set out overleaf.

Remember:
The options appraisal process should be wide ranging, transparent and recorded.
It must also refer to the remediation objectives specific to the site.

3.2.2 Waste management

Development of brownfield sites often involves the production, handling, treatment and disposal of waste. Typical wastes include demolition materials and soils (including made ground) which may or may not be contaminated. Appropriate classification and often pre-treatment, of waste is required prior to either re-use on-site or off-site disposal. Duty of Care associated with handling waste can have time and cost implications for the developer.

The definition and classification of waste are complex issues and must be fully understood at both the site investigation stage (see Chapter 2) but also in the appraisal of remediation options, the implementation of remediation works and during subsequent development. A summary of the waste management aspects of the development of land affected by contamination are provided in Annex 7.

Table 3.3 **Example of quantitative remediation evaluation criteria for hydrocarbon contamination of soils**

Priority	Remediation objective	Maximum possible score	Natural attenuation	Excavation and off-site disposal	Excavation and on-site disposal	Containment	Bioremediation *(ex situ)*
H	Eliminate further contamination of groundwater by hydrocarbons.	10	5	8	8	8	7
H	Adopt a strategy which minimises health and safety risks during implementation.	10	8	5	5	8	5
H	Ground must be able to support factory outlet and leisure centre.	10	7	7	6	5	6
H	Landfill space is scarce – neither Agency nor Local Authority wish to see material disposed off-site to landfill.	10	10	1	7	7	10
H	Time period limited to 13 months.	10	2	9	9	9	5
	Total Score High Priority Factors	**50**	**32**	**30**	**35**	**37**	**33**
L	Developer wants no long-term residual liability i.e. a clean site.	5	2	5	2	2	4
L	Regulatory acceptance.	5	2	1	3	3	5
L	Budget set at £0.75 million.	5	5	3	4	2	3
L	Developer does not want responsibility for long-term monitoring.	5	1	5	3	3	5
L	Public health issues such as noise, dust and odour are managed.	5	5	2	2	4	2
	Total Score Low Priority Factors	**25**	**15**	**16**	**14**	**14**	**19**
	Combined Total	**75**	**47**	**46**	**49**	**51**	**52**

Note: The quantitative remediation evaluation in Table 3.3 is an example of a tool which can inform the decision making process. But it does not make the decision for you.

3.2.3 Remediation treatment options

An increasing number of remediation treatment methods are available commercially in the UK. In order to arrive at the optimum strategy in terms of its ability to meet the remediation objectives careful consideration of the applications and reliability of each is required and discussions with remediation contractors at an early stage can be very helpful. Remediation treatment falls into two main categories: either involving direct action on the contaminants and their behaviour or through control of the pathway; or alternatively involving management of the receptor behaviour to alter its ability to come into contact with contaminants.

Direct action – physical techniques
Physical techniques result in the removal or separation and segregation of contaminants from soil and groundwater. Technologies consist of both *in situ* and *ex situ* methods. Physical treatments may be combined with chemical and biological treatments to provide an enhanced process and in general, do not destroy the contaminant. Physical techniques may be used to treat both organic (e.g. petroleum hydrocarbons) or inorganic (e.g. metals) contaminants. Physical techniques include:

- civil engineering approaches, for example containment using cover systems, containment using in-ground barriers, and excavation and disposal;
- physical based approaches, for example dual phase vacuum extraction, air sparging; physico-chemical washing, soil vapour extraction and soil washing;
- thermal based approaches, for example incineration, thermal desorption and vitrification.

Direct action – chemical techniques
Chemical approaches typically rely on the application of chemical compounds to react with the contaminants to convert them to harmless products which pose no risk to sensitive receptors. Chemical treatments are applicable to organic and inorganic contaminants. In many cases technology selection is driven by the ground conditions and contaminant type. Chemical techniques include:

- chemical based approaches, for example chemical oxidation using hydrogen peroxide or permanganate, chromium reduction (for example using molasses), reactive walls, soil flushing and solvent extraction;
- solidification and stabilisation based approaches, for example cement and pozzolan systems, lime based systems.

Direct action – biological techniques
Biological approaches rely on the use of micro organisms (bacteria and fungi) to carry out aerobic or anaerobic treatment of contaminants. These processes can be carried out both *in situ* and *ex situ*. Treatment technologies usually rely on creating appropriate conditions for microbial growth and are usually applicable for the treatment of organic contaminants. The technologies may rely on indigenous microbial species or can be augmented by the addition of microbes. Biological techniques include; bioventing; *in situ* bioremediation; landfarming; and windrow turning, biopiling and monitored natural attenuation (when extended time scales are available for remediation).

Management action
Management action can include the following:

- changing the land use;
- changing the site layout;
- controlling the behaviour of receptor/site use (for example through the use of planning conditions and restrictive covenants).

In particular circumstances, the development plan itself for a site affected by land contamination can be designed to meet some of the remediation objectives. For example, a residential development comprising blocks of flats with hard standing providing roads and parking areas can meet remediation objectives:

- to ensure that there is an effective barrier between residents/visitors and ground contamination; and
- to minimise leaching of contaminants into groundwater (by means of inhibiting rainwater infiltration).

However, some design elements of housing development projects on land affected by contamination, can give rise to the potential for adverse impacts (see Table 3.4 below). Such aspects will require particular consideration in the design solution.

Table 3.4 Examples of potential issues for development design options

Design element	Commentary
Building design	High rise flats may not enable gas protection measures to be as easily installed as low rise housing with ventilated sub floor voids. Houses with gardens as opposed to flats with landscaped areas will require additional thicknesses of cover to protect residents from contaminants.
Piled foundations	Potential to create preferential flow paths for contaminant migration through low permeability strata to underlying aquifers.
Specialist foundations	Incorporation of granular material (e.g. in vibro piles) may create preferential contaminant flow paths to underlying aquifers. Preferential flow paths may be created for upward migration of volatile contaminants into dwellings. Where limestone is used as below ground aggregate, acidity (low pH) in the soil may cause it to decompose to produce carbon dioxide.
Drainage	Preferential flow paths may be created for contaminants to surface water systems.
Soakaways	Soakaways encourage infiltration and can therefore enhance mobilisation of contaminants into the receiving stratum.
'Open ditch' drainage systems, storm water balancing ponds etc.	May create increased potential for unnecessary exposure of sensitive receptors for example humans to contaminants remaining on-site.
Site levels	Excavation of material to create new site levels may increase exposure to contaminants formerly at depth.

Published guidance
The Environment Agency has prepared Remediation Position Statements (available on their website www.environment-agency.gov.uk) describing fifteen of the remediation technologies used on land affected by contamination. These documents inform industry and other interested parties on how the Environment Agency applies risk based regulation to the remediation of contaminated land. The statements provide:

- a brief description of the technology;
- the applicability of the treatment process to different types of contaminated materials and contaminant groups;
- a summary of the waste management licensing implications associated with each technology; and
- relevant exemptions and exclusions from the waste management licensing regime.

The Environment Agency has also produced a series of Remedial Treatment Action Data Sheets which describe six particular remediation treatment actions for dealing with soil and groundwater contamination. The Data Sheets have been designed to assist with the evaluation and selection of the best practicable technique for remediation when dealing with one or more significant pollutant linkages. They include information on effectiveness, reasonableness, practicability and durability and are also available on the Environment Agency website www.environment-agency.gov.uk.

Available remediation technologies are summarised in Annex 8 of this guidance [reproduced from R&D66: 2000 (Environment Agency/NHBC 2000a)]. All of those listed are commercially available in the UK, although some have a limited track record. For each technology, details of the following are provided:

- technology description and contaminants that can be treated by the technology;
- media that can be treated (for example soil types, groundwater);
- treatment timescales and technical limitations.

3.3 Determination of preferred remediation strategy

From the detailed analysis of short listed remediation options, a preferred remediation strategy can be established. A remediation strategy is defined in Model Procedures (Defra/Environment Agency 2004a) as “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”. The options appraisal process should be well documented, to enable regulators and other interested parties to understand the various considerations and priorities which have informed the determination of the preferred remediation strategy.

3.3.1 Documentation and approvals

The various processes of remediation are subject to a number of regulatory controls requiring permission to proceed with the works. These are in addition to any planning consent and approvals under Building Regulations, CDM Regulations and other occupational health and safety legislation. As described above, early consultation/liaison with the relevant Regulator(s) is encouraged as it will enable a common understanding to be established at the commencement of the process, minimising the potential for subsequent delay, abortive work, etc.

The most common regulatory controls comprise:

- Conditions to a Planning Permission often require plans for works to be submitted and agreed before commencement of work on-site. Such plans normally include requirements for monitoring, verification and submission of a Verification Report;
- Waste management licensing under Waste Management Licensing Regulations 1994* (as amended) (including registered exemptions, mobile treatment licences and Environment Agency enforcement positions);
- Consignment Notes for moving Hazardous Waste (Hazardous Waste (England & Wales) Regulations 2005;
- Permits under the Pollution Prevention and Control Regulations (2000)*;
- Authorisations under Part 1 of Environmental Protection Act 1990;
- Authorisations under the Groundwater Regulations 1998 (including discharge of listed substances to groundwater);
- Consents under the Water Resources Act 1991 (including abstraction licences) and the Water Industry Act 1991 (including discharge consents and dewatering activities).

[Note: * indicates Regulations which will be replaced by the Environmental Permitting Programme (EPP) from April 2008 (Ref DEFRA 2007a (draft regulations)). The EPP is a joint Environment Agency, Defra and Welsh Assembly Government initiative that will affect the existing waste management licensing and pollution prevention control regimes. The focus is on streamlining and simplifying environmental permitting and compliance systems (e.g. the processes of obtaining, varying and transferring permits). It will be a risk based approach.]

If there is any doubt over whether an appropriate authorisation, licence or consent is or is not required then the views of the relevant Regulator should be sought before any such works are commenced. The documentation submitted to the Regulator(s) during this approvals process must include all reports of ground investigations, risk assessments, remediation options appraisal and the remediation strategy. The remediation strategy must include:

- A statement of the site-specific remediation objectives and the short list of remediation options including an explanation of the basis on which the selection of objectives and feasible remediation options was made;
- A description of the most appropriate remediation option for each relevant pollutant linkage;
- A description of the remediation strategy, how it meets the objectives for individual pollutant linkages and the site as a whole;
- The need for and extent of long-term monitoring and maintenance.

At this stage it may also be appropriate to seek community acceptance of the proposals, especially where remediation works are likely to be highly visible and result in a certain amount of disruption.

3.4 Implementation of remediation strategy

3.4.1 General considerations

Having determined the preferred remediation strategy, a plan must be developed of how this strategy is to be implemented on a particular site. Such a plan will need to take into account:

- Whether the remediation consists of a single or multiple activities;
- Whether the remediation is being carried out as part of development (i.e. integrated with site preparation, earthworks or foundation construction) or as works independent of any other construction/development works;
- How the remediation works are to be recorded such that a Verification Report can be prepared demonstrating successful implementation to all stakeholders; and
- How 'completion' of the remediation works will be determined; and the need for and scope of any long-term monitoring and maintenance.

The overall objective of the implementation plan is to ensure the successful implementation of the remediation works, its verification and documentation.

3.4.2 The implementation plan

The implementation plan should set out the design and specification for the remediation works. Important elements in the plan will:

- Confirm the remediation objective(s);
- Ensure the information describing the remediation strategy provides enough detail to enable proper specification of the work, procurement, method statements etc.;
- Determine the scope of supervision (e.g. level and experience) during the remediation works, monitoring and verification;
- Ensure all relevant regulatory requirements will be addressed and met; and
- Describe how uncertainties will be managed (e.g. how variations in ground conditions/ unexpected contamination will be dealt with).

Typically the planning for the implementation of remediation works will involve consideration of matters outside of the scientific/technical elements of the remediation process itself (as described in Section 3.1). Some of these aspects may be addressed outside of any formal implementation plan (commercial/confidential arrangements between contracting parties for instance). However, it is important that whoever is managing the implementation programme as a whole ensures that all of these aspects have been properly addressed.

Developer's requirements
The interests and constraints of the Developer/Client will frame the overall management of the project. Aspects such as the programme, the procurement, the resources and roles of the various parties together with the communication strategy will normally be defined by or agreed with the Developer.

Legal/contractual arrangements
Such arrangements will also have a strong Developer focus and will include conditions of contract, warranties, insurances as well as matters relating to technical specifications. The time taken to complete these legal agreements can be protracted, sometimes leading to the very unsatisfactory situation of work being carried out (or even being finished) before legal/contractual agreements have been reached. Insurance policies can play an important role in remediation projects but are often misunderstood. Professional indemnity insurance will insure the consultant against claims of negligence made by the client. Unless negligence is accepted or proven, a claim against this policy will not be successful. There are a number of insurance policies which can be obtained relevant to remediation works and/or specific to a site. This area is complex and advice should be obtained via specialist insurers or brokers.

There will also be conditions or agreements with the local authority or Environment Agency regulators which often define elements of the work (see Section 3.3.1). This regulatory framework needs to be understood at an early stage to ensure that all such conditions and/or legal agreements are in place in time to avoid delay to project implementation.

Financial aspects

The costs of a remediation project are clearly a critical factor. In some projects, where the remediation works are a relatively simple activity carried out as preliminary works prior to development, the overall level of expenditure can be relatively modest. Conversely, where projects are complex, including several techniques over a large area of land, with various (perhaps difficult) contaminants over a prolonged period, the total costs can be substantial, running into millions or tens of millions of pounds.

In providing a cost plan, consideration needs to be given to both sources of expenditure and possible sources of funds or cost relief. Costs will typically include:

- capital costs of the remediation;
- maintenance/running costs;
- costs of spoil disposal;
- professional fees (for supervision, data assessment, reporting etc.);
- analytical costs;
- insurance premiums;
- project management.

In addition, as with any construction project an allowance should be made for contingencies. The extent of the contingency should reflect the degree of uncertainty related to: the ground conditions; the achievement of remediation objectives etc.

The current tax relief available for remediation of brownfield sites is changing in 2008 when Derelict Land Relief is likely to be introduced (similar to the existing 150% tax relief scheme – which has been extended to cover derelict land and Japanese Knotweed). Exemption from landfill tax for site remediation will be phased out from 2012. At the time of writing this report, these measures have yet to be fully defined and reference should be made to HM Revenue and Customs www.hmrc.gov.uk.

Scientific/technical elements

These elements are usually defined in the Implementation Plan and would typically include descriptions of:

- The objectives (of each element) of the remediation and the scope of the programme of work.
- Any site constraints, operational requirements etc.
- The planned programme of site supervision, monitoring and verification.
- Arrangements for data management.
- Management of uncertainty and contingency planning.
- The proposed outline of the Verification Report.
- Anticipated long-term monitoring and maintenance.

Remember:
The implementation plan must address not only the remediation objectives (and associated technical issues) but also the requirements of the developer, the legal/contractual arrangements and the financial aspects.

3.4.3 Implementation on-site

Remediation works, whether undertaken independently or as part of development works, will normally come within the requirements of the Construction (Design and Management) Regulations 2007 (CDM Regulations) (HSC 2007a). Under these Regulations there are duties for Clients, Designers and Contractors. These duties will make sure that; reasonable steps are taken to ensure that the arrangements for managing the project are suitable and that the construction work can be carried out so far as is reasonably practicable without risk to the health and safety of any person. Reference must be made to the Regulations and Approved Code of Practice to determine the particular requirements pertinent to any specific remediation project.

Remediation works should be carried out by a contractor (and/or specialist sub contractors) with the appropriate experience and/or expertise particular to the technique(s) being adopted. Similarly, the supervision of such works must also be carried out by appropriately qualified, experienced scientists/engineers. The level of supervision must reflect the type of work being undertaken as well as the complexity of the ground conditions on the site (the geology, geochemistry, groundwater regime, soil gas regime etc.). Less experienced staff should be supported by more experienced/specialist colleagues on-site (e.g. by periodic visits etc.) and from the office. The roles and responsibilities of all the staff time (contractor, sub contractors, testing and supervisory staff etc.) must be clearly defined (e.g. in the Implementation Plan) and understood. It is also important that planned regular progress meetings are held (appropriately recorded) and that good communications are maintained between all parties throughout the programme of work.

The maintenance of a good record of the works is essential. Typically this will comprise site notes, daily diaries, progress reports, site instructions and variations, photographs, drawings etc. The use of a proforma to assist in recording of daily or periodic site visits is often helpful in promoting rigour and consistency. Such records are particularly valuable to ensure that the details of change are captured. In almost all projects, variation from initial plans is to be expected. In these circumstances, the reasons prompting change should be recorded and the adopted solution must be documented (in words and/or drawings and/or photographs). If the variation is substantial (and could, for example, depart from the remediation strategy agreed with the regulatory authority), then the relevant authority (or authorities) must be informed and their agreement to the variation sought (if practicable). In these circumstances, it must be recognised that there is often a balance to be struck between the 'ideal' envisaged in the Remediation Strategy and the practicalities of the situation on the site.

3.4.4 Verification

Verification is an important aspect of the implementation of any remediation scheme (Environment Agency 2007b (draft)). Typically, verification activities will be carried out throughout the whole of the period that remediation works are in progress and are described here in more detail in Section 3.6. The Environment Agency recommend (Defra/Environment Agency 2004a) that on completion of the Implementation Plan a Verification Plan is developed which outlines the specific data which will be collected to satisfy the objectives.

3.5 Long-term monitoring and maintenance

3.5.1 General

Long-term monitoring and/or maintenance will not be required on sites where the remediation has been designed specifically to avoid such a requirement and where the verification has adequately demonstrated that all the remediation objectives have been met within appropriate timescales. Under such circumstances, a Verification Report (sometimes called a Completion Report) can be prepared without the need for an on-going programme of monitoring and/or maintenance. Verification Reporting is described in Section 3.6.

However, on some sites, it may always have been anticipated (and therefore set out in the Remediation Strategy) that a long-term programme of monitoring and/or maintenance would be required at the completion of the remediation works themselves. Alternatively, it is possible that the need for such an on-going programme, although not anticipated in the original strategy, becomes apparent during verification. In all cases where on-going monitoring/maintenance is required, such a programme must be defined and described in a Monitoring/Maintenance Plan. Such a Plan will describe:

- The scope and context of the monitoring/maintenance activities.
- The detailed specification of the work.
- The roles and responsibilities for carrying the work out.
- The locations, frequency and duration of monitoring.
- The detail of analyses to be performed (analytical suite, limits of detection, etc.).
- The criteria for data evaluation.
- The mechanics for recording, collating and reporting data.

It is important that due consideration is given to the definition of 'failure' against acceptance criteria. For example it may not be appropriate to determine failure based on a single or limited number of monitoring points/occasions for determinands which are not critical to the site or its remediation. Similarly a relatively small exceedance of a pre-determined concentration may not signal a 'failure' of the remediation which necessitates further remediation action. Therefore it is recommended that significant failure should be defined in the Monitoring/Maintenance Plan and that it should reflect a sustained and substantial exceedance of important determinands.

The Monitoring Plan will also define the response action(s) that will be taken if the monitoring data indicates a significant failure of the remediation works/the remediation objectives. It is good practice to set out the potential response actions in an escalating hierarchy. For example, a sequence of typical response actions would be:

1. To verify the measured data;
2. To obtain supporting/ancillary data or increased frequency of monitoring;
3. To determine the nature and extent of the problem areas by further specific site investigation and monitoring (on an increased frequency and a tighter grid of locations);
4. To revise conceptual model and carry out DQRA based on all available data;
5. To determine the need for and scope of additional remediation action (modifications of existing or new technique); and
6. Implementation and verification of such remediation.

3.5.2 Maintenance activities

Maintenance activities will reflect both the nature of the remediation that has been implemented as well as the nature of the hazard being mitigated. The need for and scope of any maintenance activities will be identified in the Remediation Strategy, but is likely to be finally defined post remediation when the particulars of the scheme are a reality. The objective of maintenance work or activities is to ensure that the remediation structure continues to function and operate as designed. For example, for a perimeter gravel filled vent trench, the maintenance activity could comprise the periodic inspection (e.g. at 6 month intervals) to check for degradation of the freely venting surface (e.g. by encroachment of vegetation) and treatment by weeding, cutting back on the application of weed killer. For active gas protection systems, the programme of maintenance would consist of periodic inspection and servicing at recommended intervals by specialist engineers (often the supplier/installer). For systems such as permeable reactive barriers, periodic rejuvenation of the active element may be required. Whenever a remediation scheme is designed which includes a long-term maintenance element, it is most important that the management of such a system, in terms of both personnel and finance is well defined, robust and can guarantee longevity.

The timescale over which maintenance activities are to be carried out must also be defined. It is likely that in many cases the termination of such activity will depend upon monitoring data rather than a pre-determined number of years. For example, maintenance of the perimeter gas vent trench would be required until some other form of remediation was carried out to enable development (subject to its own remediation strategy), or the soil gas regime inside the gassing site fell to below hazardous levels. Maintenance activities must be recorded and reported to relevant stakeholders in accordance with provisions agreed in the Remediation Strategy and/or the Maintenance Plan.

3.6 Verification

3.6.1 Objective

The overall objective of verification activities is to demonstrate the achievement of the remediation objectives set out in the Remediation Strategy and Verification Plan. It is also likely that verification will be required to provide evidence that:

- planning/permit/licence conditions have been complied with;
- environmental management goals (e.g. dust generation, migration of run-off, soil gas and vapours, groundwater contamination) have been controlled.

Some particular remediation activities take place over a prolonged period of time (e.g. bioremediation of soils, groundwater treatment, etc.). In such circumstances, verification will provide data demonstrating whether the intended remediation action (such as reduction in contaminant concentration) is taking place at the expected rate. If the data is indicating that the remediation action is not occurring as predicted, action(s) must be carried out to react to that data (e.g. to increase the speed of the remediation, or the length of the remediation programme, or to decrease the remediation target etc.). Again any substantial change to the remediation objectives must be communicated to all relevant parties and agreed (as appropriate).

3.6.2 Common verification activities

Verification often involves the sampling and chemical analysis of soils on the site, using both *in situ* test kits and off-site laboratories. This data will be used to:

- Determine the nature and extent of the residual contamination (together with its location);
- Ensure appropriate classification for waste disposal; and
- Confirm the chemical nature of soils imported to site (and thus to ensure compliance with both the remediation objectives and with the contract specification).

Similarly, sampling and chemical analysis of groundwater and surface waters (at an agreed frequency and at agreed locations) is commonly undertaken. This data will demonstrate that:

- The remediation treatment is achieving the required effect on contamination concentrations;
- That any authorised discharges or construction works are not impacting groundwater or surface water contaminant concentrations to unacceptable levels; and
- That treatment of soil gases/vapours has reduced their concentrations and/or that barrier/venting systems have managed the gas/vapour regimes to meet the remediation objectives.

3.6.3 Competence

It is important that the people obtaining the verification samples/data are both competent to do so and (usually) are independent of the contractor (or specialist sub contractor). This will ensure that there can be no conflict of interest (actual or perceived) and that the samples or data are collected by people with appropriate training, equipment etc. and are properly recorded (e.g. the samples' locations are defined and the samples themselves properly described etc.).

3.6.4 Reporting

A Verification Report will be prepared on successful completion of the remediation works (which may or may not include post remediation monitoring). The Environment Agency has recently produced a Consultation Draft of guidance related to verification, including the preparation of Verification Reports (Environment Agency 2008a). In common with all such reports, the standard of presentation, the use of English (including punctuation and grammar) is important. Clear and concise communication within Verification reports will benefit all the parties involved, by reducing misunderstanding and enabling discharge of any relevant planning condition (see 3.6.5). Guidance on good practice in writing ground reports has also recently been published by the AGS (AGS 2008a).

The objective of the Verification Report is to document all aspects of the remediation works undertaken at the site. In the past, many remediation projects were carried out without being properly or permanently recorded. Subsequent further work on such sites (e.g. for redevelopment etc.) inevitably has led to major programmes of site investigations, monitoring, risk assessments etc. all of which would have been unnecessary had proper records been kept and presented in a Verification Report.

The Verification Report should describe the site, the remediation objectives, remediation techniques, verification and monitoring data in succinct text supported by drawings, figures, photographs, etc. The source data must also accompany this text, either as appendices to the main report or as reports in their own right, to which cross reference is then made. "As built" drawings are an essential component of Verification Reports. Photographs also provide good evidence of the remediation activities on the site.

Remember:
No remediation activities should take place without being properly recorded in a Verification Report.

3.6.5 Contents

The typical contents of a Verification Report are given below and described in more detail in Figure 4B, Output 5 of Model Procedures (Defra/Environment Agency, 2004a). However, it is important that the Verification Report is specific to the site and to the remediation actions that have been carried out. Normally the Verification Report will include:

1. A description of the site background;
2. A summary of all relevant site investigation reports;
3. A statement of the remediation objectives;
4. A description of the remediation works;
5. The verification data (sample locations/analytical results);
6. Project photographs;
7. As built drawings;
8. Records of consultations with Regulators;
9. Duty of Care paperwork;
10. Environmental monitoring data;
11. A description of any residual contamination;
12. Any arrangements for post remediation management.

Consideration must be given to the maintenance and accessibility of Verification Reports. To facilitate handling and storage it is increasingly common that such reports are stored on CD. However, it is also recommended that hard copies are also maintained by appropriate bodies as a safeguard (e.g. against corruption of the disk etc). Typically such reports would be retained by the Consultant or Contractor (but often this is only required by contract for 6 or 12 years), by the landowner and by the local authority regulator.

Normally, on receipt of a Verification Report, the local planning authority will take advice from their environmental health/contaminated land officers (and the Environment Agency in some circumstances) and if satisfied, formally discharge the relevant planning condition by writing to the applicant. If there is no such planning condition, the local authority or Environment Agency should nevertheless acknowledge receipt of the Verification Report. While liability remains with the developer/their insurers, they will often look to obtain ‘sign off’ of these reports by the relevant regulator(s). Regulators will not do this however, or issue their own verification of the works, but they may be willing to do one or more of the following:

- indicate whether they have reviewed the report;
- state whether they are satisfied with the level of detail provided;
- confirm that it appears to be reasonable given the data presented;
- make a statement about whether (based on the information supplied) they are currently considering the need for any enforcement action under various regulatory regimes.

It is important to understand that it remains the developer’s responsibility to ensure that they have met the remediation objectives, made the site suitable for use and adequately protected all of the relevant receptors.

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Environment Agency

Chartered Institute of Environmental Health

Guidance for the Safe Development of Housing on Land Affected by Contamination

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Glossary

Acute	A condition or disease of rapid onset/severe symptoms/brief duration.
Anaerobic	In the absence of oxygen.
Asphyxiant	A vapour or gas which causes unconsciousness or death by suffocation (lack of oxygen).
Chronic	A condition or disease of long duration involving very slow changes, often of gradual onset.
Composite sampling	Where a composite sample is formed from the combination of several sub-samples collected at different locations within the sampling area.
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 water, estuaries and coastal water to three nautical miles from the shore.
Data quality	The extent to which data about a site and its setting provide a complete, relevant, reliable and clear account of likely or true conditions.
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.
Exploratory investigation	Preliminary intrusive investigation of a site, designed to facilitate hazard assessment and conducted prior to the detailed investigations required for risk estimation.
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 general 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.
Harm	Adverse effects on the health of living organisms or other interference with the ecological systems of which they form a part. In the case of humans the definition includes harm to property.
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 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.
Large disturbed sample	Sample (usually greater than 2 kilograms in size) taken without any special precautions to maintain the original structure of the sampled material.
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.
Methanogenic	Methane producing.
Monitoring	A continuous or regular period check to determine the ongoing nature and performance of remediation, which includes measurements undertaken for compliance purposes and those undertaken to assess performance.
Non-aqueous phase liquids	Liquids that do not mix readily with water.

Non-targeted sampling	Sampling based on a systematic pattern of sampling points that are evenly distributed across sampling area.
Pathway	A route or means by which a receptor could be, or is exposed to, or affected by a contaminant.
Permeability	A measure of the ability of a medium to allow a fluid (gas or liquid) to pass through it.
Photo-ionisation director	A device that quantifies organic vapours depending on their ionisation potential.
Pollutant linkage	The relationship between a contaminant, pathway and receptor.
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.
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.
Response zone	The perforated section of standpipe which allows gas in the unsaturated zone or groundwater below the water table to enter a standpipe.
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 management	The process involved in identifying, assessing and determining risks, and the implementation of actions to mitigate the consequences or probabilities of occurrence.
Site characterisation	The process of gathering information about a site (or group of sites) and its setting(s) for the purpose of assessing and, where necessary, managing health and environmental risks.
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.
Small disturbed sample	Sample (usually 1 to 2 kilograms in size) taken without any special precautions to maintain the original structure of the sampled material.
Source	A hazardous substance or agent (for example a contaminant) which is capable of causing harm.
Supplementary investigation	Investigation carried out subsequent to a detailed investigation for the purpose of refining risk estimates, to assist in the selection of an appropriate remedial strategy, or for detailed (remedial) design purposes.

Targeted sampling	Sampling that is specifically targeted at the location(s) of known or suspect sources of contamination.
Uncertainty	A lack of knowledge about specific factors in a risk or exposure assessment including parameter uncertainty, model uncertainty and scenario uncertainty.
Undisturbed sample	Undisturbed piston samples (often 100mm in diameter) usually obtained from percussive boring equipment.
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.
Zoning	The process of delineating one or more parts of a site that justify different or specific approaches to sampling on the basis of existing or future conditions.

Appendix 2
Contact details

Association of Consulting Engineers (ACE)

Alliance House
12 Caxton Street
London
SW1H 0QL

Tel: 020 7222 6557
Fax: 020 7222 0750
Email: consult@acenet.co.uk
www.acenet.co.uk

The ACE provides information to enquirers of firms of consulting engineers who may provide services related to contamination. Normal practice is to provide names of a few firms who are members of the Association and close to the land in question. Database covers 500 different specialties including investigation and treatment of contaminated ground, water treatment, sewage treatment, hydrogeology, geotextiles and soil mechanics.

Association of Consulting Scientists Limited (ACS)

PO Box 560
Wembley
Middlesex
HA0 1NN

Tel: 020 8991 4883
Fax: 020 8991 4882
www.consultsci.uku.co.uk

The Members of the Association of Consulting Scientists are independent consultants in science and technology with practices based mainly within the UK. The Association provides a link to those member scientists practicing as consultants and enables the formation of multi-disciplinary teams to address complex problems involving many fields of expertise. Services offered range from accident investigation to radar imaging.

Association of Geotechnical and Geoenvironmental Specialists (AGS)

Forum Court
83 Copers Cope Road
Beckenham
Kent
BR3 1NR

Tel: 0208 658 8212
Fax: 0208 663 0949
Email: ags@ags.org.uk
www.ags.org.uk

Members are both consultants and contractors involved in the geo-environment offering services in ground investigation, contaminated land assessment and remediation, laboratory testing and analysis, environmental audits, hydrogeology and pollution control. Copies of the membership list and details of publications are available from the Administrator.

British Expertise

1 Westminster Palace Gardens
1-7 Artillery Row
London
SWIP 1RJ

Tel: 020 7222 3651
Fax: 020 7222 3664
Email: mail@britishexpertise.org
www.britishexpertise.org

A non-profit making multi disciplinary organisation of almost 300 independent consultancy firms and individuals. British Expertise has an environmental group representing engineers, architects, environmentalists, lawyers, economics and other consultancy disciplines. Direct enquiries are accepted to assist in identifying appropriate consultants.

British Geotechnical Association (BGA)

c/o Institution of Civil Engineers
1 Great George Street
Westminster
London
SWIP 3AA

Tel: 020 7665 2233
Fax: 020 7799 1325
Email: bga@britishgeotech.org.uk
www.britishgeotech.org.uk

The British Geotechnical Association is the principal association for geotechnical engineers in the United Kingdom. It performs the role of the ICE Ground Board, as well as being the UK member of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) and the International Society for Rock Mechanics (ISRM).

British Geological Survey (BGS)

Knigsley Durham Centre
Keyworth
Nottingham
NG12 5GG

Tel: 0115 936 3143
Fax: 0115 936 3276
Email: enquiries@bgs.ac.uk
www.bgs.ac.uk

The British Geological Survey (BGS), formed in 1835, is the world's oldest geological survey. It is the nation's principal supplier of geoscience expertise and custodian of much of the country's geoscientific information. BGS provides objective, impartial and up-to-date geoscientific information, advice and services which meet the needs of customers in the commercial, governmental, and scientific communities of Great Britain and overseas.

Chartered Institute of Environmental Health (CIEH)

Chadwick Court
15 Hatfields
London
SEI 8DJ

Tel: 020 7928 6006
Fax: 020 7827 5862
Email: info@cieh.org
www.cieh.org

The Chartered Institute of Environmental Health (CIEH) is at the forefront of environmental and public health. It sets standards and accredits courses and qualifications for the education of professional members and other environmental health practitioners. It also provides policy advice, runs educational events, publishes books and magazines, and commissions research.

Chartered Institution of Water and Environmental Management (CIWEM)

15 John Street
London
WC1N 2EB

Tel: 020 7831 3110
Fax: 020 7405 4967
Email: admin@ciwem.org
www.ciwem.org

CIWEM is a leading professional and examining body for scientists, engineers, other environmental professionals, who are committed to the application of engineering, scientific or management knowledge and expertise to the provision of works and services designed to further the beneficial management, conservation and improvement of the environment. Produces CIWEM Yearbook which includes general industry information and a listing of consultants in various areas including contaminated land.

Environment Agency (EA)

Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS32 4UD

Tel: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. It aims to ensure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Environment and Heritage Service (EHS)

Klondyke Building
Cromac Avenue
Gasworks Business Park
Lower Ormeau Road
Belfast
BT7 2JA

Tel: 0845 302 0008
Fax: 02890 569 548
Email: brian.forrest@doeni.gov.uk
www.ehsni.gov.uk

EHS takes the lead in advising on, and in implementing, the Government's environmental policy and strategy in Northern Ireland. The Agency carries out a range of activities, which promote the Government's key themes of sustainable development, biodiversity and climate change. Their overall aim is to protect and conserve Northern Ireland's natural heritage and built environment, to control pollution and to promote the wider appreciation of the environment and best environmental practices.

Environmental Industries Commission (EIC)

45 Weymouth Street
London
W1G 8ND

Tel: 020 7935 1675
Fax: 020 7486 3455
www.eic-uk.co.uk

The EIC provides environmental technology equipment and services suppliers with a strong and effective voice to influence the debate on the future of the industry among policymakers in Westminster, Whitehall and Brussels. It aims to promote constructive co-operation between the regulated, the regulators and the UK's environmental technology suppliers who serve them.

Environmental Data Services (ENDS)

11-17 Wolverton Gardens
London
W6 7DY

Tel: 020 8267 8100
Fax: 020 8267 8150
Email: post@ends.co.uk
www.ends.co.uk

Holds detailed database of consultants and offers free search service to anyone (including non-members); searches usually produce a minimum of five consultants meeting the criteria provided. ENDS Directory of Environmental Consultants is a detailed directory of over 400 consultancies which includes information on choosing a consultancy. ENDS also publish an analysis of the environmental consultancy market.

Geological Society

Burlington House
Piccadilly
London
WIJ 0BG

Tel: 020 7434 9944
Fax: 020 7439 8975
Email: enquiries@geolsoc.org.uk
www.geolsoc.org.uk

The Geological Society combines the functions of a learned society with that of a professional institution and is recognised by the DTI as the regulatory body for geology and geologists. A directory of chartered geologists is published every two years.

Health Protection Agency (HPA)

7th Floor
Holborn Gate
330 High Holborn
London
WC1V 7PP

Tel: 020 7759 2700 / 2701
Fax: 020 7759 2733
Email: webteam@hpa.org.uk
www.hpa.org.uk

The Health Protection Agency (HPA) is an independent body that protects the health and well-being of the population. The Agency plays a critical role in protecting people from infectious diseases and in preventing harm when hazards involving chemicals, poisons or radiation occur.

Institute of Environmental Management & Assessment (IEMA)

St Nicholas House
70 Newport
Lincoln
LN1 3DP

Tel: 01522 540 069
Fax: 01522 540 090
Email: info@iema.net
www.iema.net

The Institute of Environmental Management and Assessment (IEMA) is a not-for-profit organisation established to promote best practice standards in environmental management, auditing and assessment. The IEMA is now a leading international membership-based organisation dedicated to the promotion of sustainable development, and to the professional development of individuals involved in the environmental profession.

Institution of Civil Engineers (ICE)

1 Great George Street
Westminster
London
SWIP 3AA

Tel: 020 7222 7722
Fax: 020 7222 7500
www.ice.org.uk

Produces a publication (though not updated) in conjunction with Institute of Biology, Institution of Chemical Engineers, Royal Society of Chemistry, listing organisations offering consultancy services. Information can be supplied as lists of references, external databases, searches, photocopies of articles, etc. for historical information on sites and published information on contaminated land.

Institution of Structural Engineers (IStructE)

11 Upper Belgrave Street
London
SWIX 8BH

Tel: 0207 235 4535
Fax: 0207 235 4294
www.istructe.org

IStructE is the world's leading professional body for structural engineering. It is the appropriate source of relevant and considered opinion on all structural engineering and public safety issues in the built environment. Its image is one of safety, efficiency and excellence, both of its operations and in the standards of its members. The Institution qualifies its members by examinations that test professional competence in structural engineering design.

Landscape Institute

33 Great Portland Street
London
W1W 8QG

Tel: 020 7299 4500
Fax: 020 7299 4501
Email: mail@landscapeinstitute.org
www.landscapeinstitute.org

The Landscape Institute is the professional body for landscape architects, landscape managers and landscape scientists. The Institute publishes a Directory of Registered Landscape Practices in January each year, which lists practices by area. A short summary of the expertise of each practice is included and further advice on the selection of landscape consultants is available through a nomination service.

National House-Building Council (NHBC)

Buildmark House
Chiltern Avenue
Amersham
HP6 5AP

Tel: 0844 633 1000
Fax: 0844 633 0022
Email: technicalenquiries@nhbc.co.uk
www.nhbcbuilder.co.uk

NHBC is the standard setting body and leading warranty provider for new and newly converted homes in the UK. It provides a broad range of services to the house-building and wider construction industry. NHBC is also internationally recognised as an example of best practice.

Royal Institution of Chartered Surveyors (RICS)

12 Great George Street
Parliament Square
London
SWIP 3AD

Tel: 0870 333 1600
Fax: 020 7334 3811
Email: contactrics@rics.org
www.rics.org

The RICS Information Centre holds a database of members' firms and can search for those offering services required in the appropriate area.

Royal Town Planning Institute (RTPI)

41 Botolph Lane
London
EC3R 8DL

Tel: 020 7929 9494
Fax: 020 7929 9490
Email: online@rtpi.org.uk
www.rtpi.org.uk

Provides information to inquirers about firms of consulting town planners who may provide services in respect of contamination. Normal practice is to provide names of a few firms.

Royal Society of Chemistry (RSC)

Burlington House
Piccadilly
London
W1J 0BN

Tel: 020 7437 8656
Fax: 020 7437 8883
www.rsc.org

The RSC produced a publication in 1988 (not updated) in conjunction with the Institute of Biology, Institution of Chemical Engineers, and Institution of Civil Engineers, listing organisations offering consultancy services for the investigation and assessment of contaminated land.

Scottish Environment Protection Agency (SEPA)

Erskine Court
Castle Business Park
Stirling
FK9 4TR

Tel: 01786 457700
Fax: 01786 446885
www.sepa.org.uk

SEPA is Scotland's environmental regulator and adviser. Their role includes controlling pollution and working with others to protect and improve the environment.

Specialist in Land Condition (SiLC)

c\o Institute of Environmental
Management & Assessment
70 Newport
Lincoln
LN1 3DP

Tel: 01522 540 069
Fax: 01522 540 090
Email: info@iema.net
www.silc.org.uk

A SiLC Professional and Technical Panel was established to develop a system for the registration of individuals completing the Land Condition Record (LCR). An individual who becomes registered will be a "Specialist in Land Condition" and be known as a SiLC. The use of a registered SiLC will give the highest level of credibility to the information that is included in the LCR.

UK Accreditation Services (UKAS)

21-47 High Street
Feltham
Middlesex
TW13 4UN

Tel: 020 8917 8400
Fax: 020 8917 8500
Email: info@ukas.com
www.ukas.com

Technical enquiry office answers specific questions/enquiries relating to laboratories involved in chemical analysis of contaminated land. All accreditation schedules are available from their website.

Appendix 3
The regulatory regimes for Northern Ireland, Wales and Scotland

Northern Ireland

The Northern Ireland Assembly was established as part of the Belfast Agreement and it is the prime source of authority for all devolved/transferred matters (including environment and planning) and has full legislative and executive authority. Devolution powers became the responsibility of the Northern Ireland Assembly on the 2nd December 1999. The Executive was subsequently suspended and Direct Rule restored on the 11th February 2000. Restoration of devolution subsequently took place on 30th May 2000. Twenty four hour suspensions also took place in August and September 2001. On the 14th October 2002 the Assembly was again suspended and then formally dissolved on the 28th April 2003. Subsequently the Assembly was restored to a state of suspension following elections in November 2003 with the Assembly finally being restored on 8th May 2007.

The Environment and Heritage Service (EHS) is the largest Agency within the Department of the Environment (DOE NI), one of the eleven Northern Ireland Departments created in 1999. The EHS takes the lead in advising on, and in implementing, the Government's environmental policy and strategy in Northern Ireland.

The Planning Service, another Agency which comes under the umbrella of the DOE NI, is responsible for developing and implementing Government planning policies and development plans in Northern Ireland.

Part 3 of the Waste and Contaminated Land (Northern Ireland) Order 1997 contains the main legal provisions for the introduction of a contaminated land regime in Northern Ireland. The Order was enacted in 1997 but the regime is not yet in operation. The provisions within Part 3 are virtually identical to those provided by part 2A and would establish a regime whereby local authorities are under a duty to investigate and identify contaminated land and identify those responsible for its remediation.

In terms of provision of technical guidance for regulators to assist them in the determination of contaminated land the DOE NI references the DEFRA SGV Task Force and CLEA publications.

The primary legislation governing planning in Northern Ireland is the Planning (Northern Ireland) Order 1991 (as amended). This is backed up by secondary legislation and planning policy, including planning policy statements (PPSs) and area plans. However there is currently no specific PPS addressing development on potentially contaminated land.

Planning applications are determined by the Planning Service with local councils, along with other government departments, acting as consultees to the approval process.

Despite the lack of guidance the Planning Service, in considering planning applications for brownfield sites, will impose conditions for site investigation and remediation that broadly mirror the requirements of part 3/Part 2A.

Wales

Both the Environment Protection Act 1990 and the Environment Act 1995 were issued on a UK wide basis, so the same principles of Part 2A legislation are applicable. In July 1997 the UK Government published a white paper outlining proposals for devolution. In Wales a referendum was held in September 1997 and the result led to the Government of Wales Act 1998 being issued thus establishing the National Assembly for Wales (NAW) with powers being transferred on 1st July 1999. Since this time subordinate legislation has been introduced in Wales that details how the provisions of an Act of Parliament will apply. Hence the reason for different effects in Wales to that of England.

The elected Assembly Members effectively delegated their powers for implementation of policies and legislation to the Welsh Assembly Government (WAG). One of the subject areas within WAG is Environment Planning & Countryside, which covers the policies and subordinate legislation relevant to land contamination. The preliminary legislation was The Contaminated Land (Wales) Regulations 2001 Welsh Statutory Instrument 2001 No. 2197 (W.157) which came into force on 01st July 2001. This has now been revoked and replaced by The Contaminated Land (Wales) Regulations 2006 Welsh Statutory Instrument 2006 No. 2989 (W.278) which came into force on 10th December 2006. These include the changes for appeals on Remediation Notices, which are required to be made to NAW. The Radioactive Contaminated Land (Modification of Enactments) (Wales) Regulations 2006 were implemented at the same time.

Current Statutory Guidance relevant to Wales is the Part 2A Statutory Guidance on Contaminated Land (2006) issued by WAG. This comprises Guidance previously issued in November 2001 and further guidance to accompany other modifications such as the introduction of radioactivity. The principle regulators of the Part 2A process are Environment Agency Wales and as appropriate the local authority responsible for the site in question. As in England the use of the CLEA UK model and the relevant SGV and TOX reports are applicable in Wales.

In respect of Planning the circular 022/87 (WO) prepared by DETR (Department of Environment, Transport and the Regions) on Development of Contaminated Land remains applicable for outlining the requirements associated with new developments, including change of use. The document states that contamination is a material planning consideration, but is ambiguous in a number of areas. It does however indicate that an investigation will normally be required where the previous history of the site suggests contamination.

Planning Policy Wales (2002) outlines that the physical constraints on the land are to be taken into account at all stages of the planning process and this is in the context of land instability and land contamination. It also explains that LPA's (Local Planning Authorities) should be aware of the requirements of Part 2A and ensure that their policies and decisions are consistent with it. This implies that the methods used in assessing land for Part 2A purposes should be applied within the planning regime. Accordingly the concept of risk assessment as a tool to help direct development on a suitable for use basis is appropriate as in England.

PPS23 does not apply in Wales, however it may be referred to as good practice, though this may be open to challenge. In Wales Technical Advice Notes (TAN) are used as Planning Policy Statements and currently there is no TAN applicable to land contamination in Wales. WAG is considering the preparation of a TAN and it is understood that this will look at the suitability of PPS23 for Wales, though no timetable for delivering this has been made.

Land Contamination: A Guide for Developers prepared on behalf of the Welsh Local Government Association, Environment Agency Wales & WAG was issued in July 2006. Whilst this is not statutory guidance, it helps confirm good practice and broadly details the risk assessment process in line with CLR11 (Model Procedures).

Scotland

Since the passing of the Scotland Act and the official convening of the Scottish Parliament and the Scottish Executive on the 1st July 1999 devolved matters, including the environment and planning, have been the responsibility of Scottish Ministers.

There are two regulatory enforcement bodies in Scotland with duties and powers in terms of identification and remediation of contaminated land and development of brownfield sites; Local Authorities and the Scottish Environment Protection Agency (SEPA) which was established in 1996.

The current structure of local government in Scotland was established by the Local Government (Scotland) Act 1994. Since the passing of the Act Scotland has been divided into 29 unitary authorities and 3 island authorities. It is the responsibility of the Scottish Executive to implement Part 2A of the Environmental Protection Act, 1990. Scottish Ministers therefore implemented The Contaminated Land (Scotland) Regulations 2000 (SI2000/178) (the 2000 Regulations) with accompanying statutory guidance on the 14th July 2000.

The 2000 Regulations were replaced on the 1st April 2006 by the Contaminated Land (Scotland) 2005 Regulations (the 2005 Regulations). The 2005 Regulations amended Part 2A of the Environmental Protection Act 1990 and the 2000 Regulations in the light of the Water Environment and Water Services (Scotland) Act 2003. Guidance on the 2005 Regulations was published in June 2006 in the form of Paper SE/2006/44 (Statutory Guidance; Edition 2) by the Scottish Executive. The document replaces in its entirety the guidance issued July 2000.

Contaminated land was defined in the 2000 Regulations where *pollution of controlled waters is being, or is likely to be caused*. This meant that any degree of pollution of controlled waters could have resulted in the land being designated as contaminated. The 2005 Regulations addressed the anomaly whereby *trivial* amounts of pollution resulted in land being designated as contaminated by introducing a requirement that pollution be "significant" or likely to be "significant" in relation to the water environment.

Unlike England and Wales the 2005 Regulations do not include radioactive contamination. The Radioactive Contaminated Land (Scotland) Regulations 2007 came into force in Scotland on the 30th October 2007. The Regulations make provision for Part 2A to have effect with modifications for the purpose of the identification and remediation of radioactive contaminated land.

In terms of guidelines for the assessment of contaminated land, CLEA publications and the CLEA model are used to aide identification of potentially contaminated land. The following table summarises the duties and powers of Local Authorities and SEPA under Part 2A.

Local Authority – duties	**SEPA – duties**
Inspect their areas to identify contaminated land and designate special sites	Provide site specific advice to local authorities on contaminated land
Ensure remediation of land identified as contaminated land	Maintain remediation register of special sites
Maintain remediation registers for contaminated land	Prepare a national report on the state of contaminated land
Consult SEAP on the pollution of the water environment	Require remediation of special sites
Local Authority – powers	SEPA – powers
Recover costs for remediation undertaken itself	Recover costs for remediation undertaken itself

When brownfield or contaminated sites are being developed, Local Authorities require that the need for remediation is determined using guidance provided by Planning Advice Note (PAN) 33.

PAN 33 uses the Suitable for Use Approach. The approach focuses on the risks caused by land contamination and recognises that the risks presented by any given level of contamination will vary greatly according to the use of the land and a wide range of other factors such as the underlying geology.

The Suitable for Use Approach comprises three elements:

- Ensuring that land is suitable for its current use;
- Ensuring that land is made suitable for any new use as planning permission is given for that use; and
- Limiting the requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to the current use or future use for which planning permission is being sought.

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Annex 1
Site walkover survey – aide memoire

Site name:

Address:

Code name/no:

Site area (m^2):

NGR:

Date inspection undertaken:

Inspected by:

Site contact (name and title):

Weather:

General site description/current site uses

Note **activities** being undertaken on the site, **site access** details and give a description of the **site boundary.** If processes take place on the site you will need to ask rather than just note. Mark these on the plan or draw a sketch map at this stage.

Surface cover of site
(e.g. buildings, hardstanding, grass etc. Potential for surface water infiltration.)

Building and hardstanding materials
Details of materials (type and approximate quantities) that make up site buildings and hardstanding (take some photos).

Visible evidence of contamination
*Look for vegetation dieback, discoloured ground, seepage of odorous/discoloured liquid. Any evidence of gas protection measures (vent pipes/air bricks) – **take photos**. Look at the land adjacent to the site.*

Presence of vegetation and invasive weeds
Record presence condition of trees, plants and shrubs etc. Look for evidence of invasive weeds [Japanese Knotweed; Giant Hogweed; Himalayan Balsom on land and Australian swamp stonecrop; Parrot's feather and floating pennywort in surface water bodies]. See Environment Agency website for Guidance for control of invasive weeds which includes illustration.

Presence of wildlife
Record presence of nesting birds. Is the site within an area of ecological importance e.g. SSSI or National Park. Is Wildlife on-site protected in accordance with the Wildlife and Countryside Act 1981 and 1985 – see Defra website for information on the Wildlife and Countryside Act.

Presence of asbestos
Age of building, pipe lagging, ceiling tiles; brake pads; if evident what state of repair is it in? Has there been an asbestos survey undertaken on the site? Implications for redevelopment?

Presence of PCBs
(Polychlorinated biphenyls, production banned since 1979 but still may be present on-site as a transformer coolant in electrical components. Require specialist disposal by incineration).
Has there been a survey? Is there any correspondence with the Electricity Company?

Storage of materials and old tanks
(Check for evidence of wastes and chemicals stored both above and below ground, mark location of storage areas on-site plan.) Are any above ground tanks bunded, what is the condition of the bund, any staining? Are there any underground storage tanks which have been decommissioned? Were they removed? Were they backfilled? Was any ground testing done at the time?

Services

Overhead or buried services? (overhead wires, sewers, gas main, petrol interceptors, where do drains discharge to?) Are service plans available on-site? Are any surface water drains in sensitive areas, e.g. by storage areas?

History of use

Cite evidence, conclusions and sources. There may be relevant street/house/locality or pub names within 250m of the site. Have a look.

Geology, hydrology, hydrogeology

Before the visit make sure you know the basic environmental setting of the site and check that it is consistent with your observations.

Site geology
Describe any surface outcrops/exposures or exposures of soils/rocks in any areas of excavations, cuttings etc.

Any previous investigations (ask on-site, e.g. when extensions built, when tanks excavated)
(contaminative or geotechnical.) Any previous audits, Environment Agency Pollution prevention audits.

Site topography
Flat, sloping etc. Are there any obvious discontinuities within the site or between the site and its neighbours. Any cuttings, embankments, mounds?

Surface water bodies and courses
(Name, type, quality.)

Hydrogeology
(e.g. wells, abstraction, seepages, aquifers.)

Any other relevant information

(Include information on any underground structures or on the presence of any trees.)

Site neighbours

Nature of surrounding land
(e.g. industrial, residential, commercial, SSSIs.)

Approximate distance to nearest properties

a) industrial

b) residential: have there been any complaints? have these been resolved? Were the Local Authority involved? Was any enforcement action taken?

c) commercial

Observations on neighbouring sites
(Note: e.g. spillages, apparent poor site management.)

Photos taken

Note the picture number together with a brief description stating the direction of view, what you are taking the photo of and for, other points of interest in foreground/background etc. It may be easier to do this as annotations on a site plan.

Picture No.	Description

Annex 2
Site sensitivity assessment for the water environment

A Groundwater

It is Important that the characterisation of site sensitivity is logical, transparent, robust and repeatable. A scheme describing terms of sensitivity for groundwater, surface waters and ecology is present below. The assessment of site sensitivity by personnel with an appropriate, relevant technical background will increase the technical rigour and repeatability of the assessment.

Sensitivity assessment	**Standard response**	**Implications/need for further work** *(subject to nature of source and pathway)*
H1 (Very high)	Highly vulnerable aquifer, actively used in vicinity of site with short travel times to sources of supply or sensitive watercourses. Likely to be within an inner or outer groundwater protection zone (Zones I or II under EA protection policy). All contaminant releases to the ground environment of concern.	Extensive groundwater and soil clean-up or removal is likely to be needed if a source and pathway exist. Potential for major on-site and off-site liabilities. Further, detailed risk assessment essential and is likely to be required by the Regulators. Could be long-term residual liabilities with major cost implications and potential high risk of prosecution.
H2 (High)	Major or minor vulnerable aquifer with probable use nearby (either direct abstraction or baseflow to sensitive watercourses and springs). Likely to be within Outer or Source Catchment protection zones (Zones II or III). Most contaminant releases to the ground environment of concern.	Significant groundwater remediation measures may be required, after detailed risk assessment, which is likely to be required by the Regulators. Soil decontamination or isolation probably necessary. Potential for significant on-site and off-site liabilities, including treatment and/or replacement of local potable water supplies. Substantial cost implications and potential moderate/high risk of prosecution.
M1 (Moderately high)	Recognised major or minor aquifer, moderately vulnerable, with probable use (either direct or via baseflow to a sensitive watercourse). Within formal protection zone or catchment of authorised abstractions for potable or other high quality uses. Minor, short-term releases of contaminants may be tolerable.	Following risk assessment, soil decontamination or isolation may be required. Localised groundwater clean-up may be needed but large scale clean-up unlikely unless source is substantial and toxic. Possible off-site liabilities such as replacement/treatment of local potable water supplies. Moderate cost implications and potential moderate risk of prosecution.
M2 (Moderate)	Minor aquifer, low to moderately vulnerable, but with possible uses in general area, particularly for domestic supplies. May provide pathway to surface water.	Risk assessment may indicate need for localised clean up/isolation of soil and groundwater only, but may be some off-site liabilities e.g. local potable water supplies. Moderate to low cost implications. Potential prosecution less likely.
L1 (Low)	Permeable strata/minor aquifer near surface, but no apparent use and low vulnerability (may also be a significant aquifer but downgraded by long-term/permanent degradation of water quality). May provide pathway to surface watercourse at distance.	Localised clean-up/isolation of soil and groundwater only. Unlikely to be significant off-site liabilities or action by statutory authorities with respect to groundwater. Low cost implications.
L2 (Very low)	Not a recognised aquifer, but strata beneath site may retain a small amount of contaminated liquid but there is likely to be limited vertical penetration. High potential for surface runoff or ponding.	Clean-up/isolation of soil and contained groundwater only, in immediate vicinity of release. Unlikely to be off-site liabilities or action by statutory authorities with respect to groundwater. Low cost implications.

B Surface water (excluding coastal waters)

Sensitivity assessment	Standard response	Implications/need for further work *(subject to nature of source and pathway and no short circuiting by artificial drainage systems)*
H1 (Very high)	High quality watercourse (GQA A or B) within close proximity (less than 250m) of site or with potential for rapid transmission of pollutants to that watercourse via a fissured aquifer. or interconnected unclassified drain or stream.	Potential for major pollution incident with fish kills, risk to river users etc. Major cost implications for remediation measures and with respect to penalties on prosecution. Potential for major adverse publicity.
H2 (High)	Site within catchment and reasonable proximity (less than 500m) of high quality watercourse (GQA A/B) or with potential transmission of pollutants via baseflow from an aquifer with little subsurface attenuation or via an interconnected unclassified drain or stream.	Potential for significant pollution incident that requires remedial measures and likely to involve a prosecution and adverse publicity. Substantial cost implications.
M1 (Moderately high)	Site within catchment and reasonable proximity (less than 500m) of a moderate quality watercourse (GQA C/D) or 500-1000m of a high quality watercourse (GQA A/B). Also where there is potential transmission of pollutants via baseflow with little subsurface attenuation or via an interconnected unclassified drain or stream.	Potential for significant pollution incident that requires remedition measures. Possible prosecution, particularly if contamination is likely to be visible or result in public complaints.
M2 (Moderate)	Site within catchment of and relatively close (less than 1000m) to moderate or poor quality (GQA C to F) watercourse that may be subject to planned improvement by attainment of surface water quality objectives. May be potential for transmission of pollutants via baseflow from a highly permeable formation.	Minor incidents are unlikely to attract third party liabilities , but action by statutory authorities likely if contamination is visible or repeated.
L1 (Low)	Within catchment of and over 250m from generally poor quality watercourse (GQA E or F) that is unlikely to improved by current or foreseeable surface water quality objectives or at distance (over 1000m) from a good quality watercourse with no interconnecting drains or baseflow from fissured strata.	Unlikely to be third party liabilities or action from statutory authorities from surface water viewpoint.
L2 (Very low)	No surface water within general area of the site (at least 250m) or closed drainage within site. Little or no potential for significant transmission via baseflow and no interconnecting drains.	Liabilities restricted to site itself (localised soil contamination or ponding) or associated with groundwater.

C Coastal waters

Sensitivity assessment	**Standard response**	**Implications/need for further work** *(subject to nature of source and pathway and no short circuiting by artificial drainage systems)*
H1 (Very high)	Within 100m of a sensitive coastal water, that is, a recognised bathing water, a "more sensitive area" (as defined under the Urban Wastewater Treatment Directive) or a marine SSSI or at a greater distance but with a direct connection via a stream or a highly fissured aquifer to such a coastal water with the potential for rapid flow to that water.	Potential for major environmental health risks and ecological damage. Probability of high remedial costs, prosecution and adverse publicity.
H2 (High)	As above, within 250m or with a relatively rapid route of transmission or within 100m of a "less sensitive area".	
M1 (Moderately high)	Within 500m of a bathing water or a defined sensitive area (see above); with possibility of diffuse flow via groundwater seepages at coastline or with connection via nearby watercourses.	LESS DATA AVAILABLE FOR COASTAL SITES TO GIVE GENERALISED ASSESSMENTS OF POTENTIAL LIABILITIES.
M2 (Moderate)	Within 500m of a coastal water (undefined), with possibility of diffuse flow via groundwater seepages at coastline or with connection via nearby watercourses.	
L1 (Low)	No coastline nearby (within 1km), but with possibility of diffuse groundwater seepages at coastline or connection via nearby watercourses.	Liabilities initially associated with watercourses or groundwaters.
L2 (Very low)	No coastline nearby (within 1km) and/or no direct connection via surface or ground water.	No liabilities likely.

D Artificial drainage systems

Sensitivity assessment	**Standard response**	**Implications/need for further work** *(subject to nature of source and pathway and no short circuiting by artificial drainage systems)*
H1 (Very high)	Extensive land use/industrial history, successive building development. Steep surface slopes(rapid travel times with little opportunity for dilution/ interception facilities) or close proximity (within 250m) to surface watercourses or high sensitivity groundwater. Former mining areas where subsurface mine drains are present or suspected. Detailed drainage records absent.	Probability of interconnection of artificial and natural drainage systems, with consequent risks to sewers, surface and ground water. Potential unconsented connections and discharges on- and off-site with third party pipes/structures, risk of third party action and additional effluent treatment costs. Potential damage to site fabric and structures due to leakages and collapse. Major cost implications for investigation and implementation of remedial measures. Drainage investigation and risk assessment essential.
H2 (High)	As above, but shallower slopes (longer retention times in drains) or more distant (over 250m) to surface watercourses or with detailed records of drainage systems.	As above, but potentially lower investigatory and remedial costs. Drainage investigation and risk assessment essential.
M1 (Moderately high)	More than one phase of site development with limited historic records of drainage systems (sewers, surface water, pipelines). Over 250m from surface watercourse.	As above, but less extensive drainage investigation and reduced investigation and remedial costs.
M2 (Moderate)	More than one phase of site development with detailed historic records of drainage systems (sewers, surface water, pipelines).	As above, costs likely to be dependent on-site processes and degree of maintenance of existing drainage systems.
L1 (Low)	Recent (greenfield) development, with recorded and low intensity drainage systems or older sites with thoroughly investigated and recorded drainage systems, drainage risk assessment and implementation of remedial measures. Within 250m of surface watercourses or on low permeability strata. No mine drains.	Leakages from drains may contaminate soil locally and eventually reach a watercourse. Low risk of third party action.
L2 (Very low)	Recent (greenfield) development, with recorded and low intensity drainage systems, or older sites with thoroughly investigated/recorded drainage systems, drainage risk assessment and implementation of remedial measures. Remote from surface watercourses, all drainage to adopted sewers and with no permeable strata within 10m of the site surface. No mine drains.	Leakages from drains may contaminate soil locally.

Annex 3
Key contaminants associated with industrial uses of land
[Reproduced from R&D66: 2000]

Comprehensive lists of contaminants associated with industrial uses of land appear in each of the Department of the Environment Industry Profiles. The number of contaminants associated with industrial uses varies, with some profiles listing over 100 different substances. The most significant contaminants associated with each, selected on the basis of frequency of occurrence, existence of information on hazards and availability of analytical methods are listed in the two following tables: Metals, semi-inorganic chemicals; and Organic chemicals. The tables are taken from the CLR report on contaminants for the assessment of land (CLR8).

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																				
	Metals and semi-metals												Inorganic chemicals								
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN- free	CN- complex	NO_3^-	SO_4^{2-}	S^{2-}	Asbestos	B	pH	So
Airports					✓	✓								✓				✓		✓	
Animal and animal products processing works	✓			✓	✓											✓	✓				
Asbestos manufacturing works				✓	✓																
Ceramics, cement and asphalt manufacturing works	✓			✓	✓	✓	✓	✓	✓			✓					✓	✓		✓	
Charcoal works	✓			✓	✓	✓	✓	✓		✓		✓	✓		✓	✓		✓		✓	
Chemical works: coatings and printing inks manufacturing works		✓		✓	✓	✓	✓		✓			✓				✓		✓		✓	✓
Chemical works: cosmetics and toiletries manufacturing works				✓								✓					✓	✓		✓	
Chemical works: disinfectants manufacturing works		✓			✓		✓	✓				✓				✓				✓	
Chemical works: explosives, propellants and pyrotechnics manufacturing works	✓	✓			✓	✓	✓	✓	✓			✓			✓	✓		✓	✓	✓	
Chemical works: fertiliser manufacturing works				✓	✓	✓	✓		✓			✓						✓		✓	
Chemical works: fine chemicals manufacturing works	✓			✓	✓		✓	✓			✓				✓	✓		✓			

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																				
	Metals and semi-metals												Inorganic chemicals								
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN- free	CN- complex	NO_3^-	SO_4^{2-}	S^{2-}	Asbestos	B	pH	So
Chemical works: inorganic chemicals manufacturing works	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	
Chemical works: linoleum vinyl and bitumen-based floor covering manufacturing works	✔											✔				✔		✔		✔	
Chemical works: mastics, sealants, adhesives and roofing felt manufacturing works	✔	✔			✔	✔	✔	✔				✔				✔		✔		✔	
Chemical works: organic chemicals manufacturing works	✔				✔	✔	✔		✔		✔	✔	✔			✔		✔		✔	
Chemical works: pesticides manufacturing works	✔				✔	✔	✔	✔				✔						✔		✔	
Chemical works: pharmaceuticals manufacturing works	✔				✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Chemical works: rubber processing works (including works manufacturing tyres and other rubber products)																	✔				✔
Chemical works: soap and detergent manufacturing works																				✔	
Dockyards and dockland	✔			✔	✔	✔	✔	✔	✔			✔				✔	✔	✔			
Dry cleaners	✔			✔	✔	✔	✔	✔		✔		✔	✔		✔	✔		✔		✔	

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																				
	Metals and semi-metals												Inorganic chemicals								
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN- free	CN- complex	NO_3^-	SO_4^{2-}	S^{2-}	Asbestos	B	pH	So
Engineering works: aircraft manufacturing works				✔	✔	✔	✔		✔			✔	✔		✔	✔		✔		✔	
Engineering works: electrical and electronic equipment manufacturing works (including works manufacturing equipment containing PCBs)	✔			✔	✔	✔	✔	✔	✔			✔			✔	✔	✔	✔	✔	✔	
Engineering works: mechanical engineering and ordnance works	✔		✔	✔	✔	✔	✔	✔	✔		✔	✔	✔		✔	✔		✔	✔	✔	
Engineering works: railway engineering works	✔			✔	✔	✔	✔		✔		✔	✔	✔		✔	✔		✔	✔	✔	
Engineering works: shipbuilding repair and shipbreaking (including naval shipyards)	✔				✔	✔	✔					✔	✔					✔		✔	
Engineering works: vehicle manufacturing works				✔	✔	✔	✔		✔	✔		✔	✔		✔	✔	✔	✔		✔	
Fibreglass and fibreglass resin manufacturing works	✔			✔	✔	✔	✔	✔		✔		✔	✔		✔	✔		✔		✔	
Gasworks, coke works and other coal carbonisation plants	✔			✔	✔	✔	✔	✔	✔		✔	✔	✔	✔		✔	✔	✔		✔	✔
Glass manufacturing works	✔			✔	✔	✔	✔	✔				✔	✔		✔	✔		✔	✔	✔	

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																				
	Metals and semi-metals												Inorganic chemicals								
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN- free	CN- complex	NO_3^-	SO_4^{2-}	S^{2-}	Asbestos	B	pH	So
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works				✔	✔	✔	✔		✔			✔	✔		✔	✔	✔	✔	✔	✔	
Metal manufacturing, refining and finishing works: iron and steel works	✔				✔		✔		✔		✔	✔	✔			✔	✔	✔		✔	✔
Metal manufacturing, refining and finishing works: lead works	✔			✔	✔	✔	✔					✔				✔	✔	✔		✔	
Metal manufacturing, refining and finishing works: non-ferrous metals(excluding lead works)				✔	✔	✔	✔	✔	✔		✔						✔	✔	✔		
Metal manufacturing, refining and finishing works: precious metal recovery works	✔			✔	✔	✔	✔	✔				✔			✔	✔	✔	✔		✔	
Oil refineries and bulk storage of crude oil and petroleum products	✔					✔	✔		✔				✔				✔	✔		✔	
Photographic processing industry	✔			✔	✔	✔	✔	✔		✔		✔	✔		✔	✔		✔		✔	
Power stations (excluding nuclear power stations)	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔				✔	✔	✔		✔	
Printing and bookbinding works	✔			✔	✔	✔	✔	✔		✔		✔	✔		✔	✔		✔		✔	
Pulp and paper manufacturing works	✔			✔	✔											✔		✔		✔	
Railway land	✔			✔	✔	✔	✔		✔		✔					✔		✔			

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																				
	Metals and semi-metals												Inorganic chemicals								
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN- free	CN- complex	NO_3^-	SO_4^{2-}	S^{2-}	Asbestos	B	pH	So
Road vehicle servicing and repair: garages and filling stations	✔				✔	✔	✔					✔						✔		✔	
Road vehicle servicing and repair: transport and haulage centres	✔				✔	✔	✔				✔	✔						✔		✔	✔
Sewage works and sewage farms	✔			✔	✔	✔	✔	✔	✔			✔	✔		✔	✔	✔	✔		✔	
Textile works and dye works	✔			✔	✔	✔		✔							✔	✔		✔	✔	✔	
Timber products manufacturing works	✔			✔		✔	✔					✔				✔			✔		
Timber treatment works	✔				✔	✔						✔					✔		✔	✔	
Waste recycling, treatment and disposal sites: drum and tank cleaning and recycling plants																	✔	✔		✔	
Waste recycling, treatment and disposal sites: hazardous waste treatment plants	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔			✔			✔		✔	
Waste recycling, treatment and disposal sites: landfills and other waste treatment or waste disposal sites	✔			✔	✔	✔	✔		✔			✔					✔	✔		✔	
Waste recycling, treatment and disposal sites: solvent recovery works				✔	✔	✔	✔		✔			✔			✔					✔	
Waste recycling, treatment and disposal sites: metal recycling sites	✔	✔		✔	✔	✔	✔	✔	✔			✔	✔			✔	✔	✔		✔	

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants: Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Airports		✔		✔	✔		✔				✔			
Animal and animal products processing works	✔				✔	✔	✔		✔					
Asbestos manufacturing works					✔	✔	✔				✔			
Ceramics, cement and asphalt manufacturing works		✔		✔		✔					✔			
Charcoal works		✔			✔		✔				✔			
Chemical works: coatings and printing inks manufacturing works	✔				✔	✔	✔							✔
Chemical works: cosmetics and toiletries manufacturing works		✔			✔	✔	✔							
Chemical works: disinfectants manufacturing works	✔		✔		✔	✔				✔	✔	✔		
Chemical works: explosives, propellants and pyrotechnics manufacturing works	✔	✔		✔	✔		✔				✔			
Chemical works: fertiliser manufacturing works				✔		✔					✔			
Chemical works: fine chemicals manufacturing works	✔	✔			✔	✔					✔	✔		
Chemical works: inorganic chemicals manufacturing works						✔								
Chemical works: linoleum vinyl and bitumen-based floor covering manufacturing works	✔			✔	✔	✔	✔			✔	✔			✔
Chemical works: mastics, sealants, adhesives and roofing felt manufacturing works	✔			✔	✔	✔	✔							

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants: Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Chemical works: organic chemicals manufacturing works	✔	✔			✔						✔			
Chemical works: pesticides manufacturing works	✔		✔		✔		✔	✔	✔		✔	✔		✔
Chemical works: pharmaceuticals manufacturing works				✔	✔	✔	✔			✔	✔			
Chemical works: rubber processing works (including works manufacturing tyres and other rubber products)	✔				✔		✔				✔			
Chemical works: soap and detergent manufacturing works		✔		✔	✔	✔						✔		
Dockyards and dockland	✔					✔	✔	✔		✔	✔			
Dry cleaners					✔		✔				✔			
Engineering works: aircraft manufacturing works					✔		✔				✔			
Engineering works: electrical and electronic equipment manufacturing works (including works manufacturing equipment containing PCBs)					✔		✔				✔			
Engineering works: mechanical engineering and ordnance works	✔	✔			✔	✔	✔				✔			
Engineering works: railway engineering works					✔	✔	✔				✔			
Engineering works: shipbuilding repair and shipbreaking (including naval shipyards)		✔		✔	✔		✔							✔
Engineering works: vehicle manufacturing works	✔	✔		✔	✔	✔	✔				✔			
Fibreglass and fibreglass resin manufacturing works	✔	✔			✔		✔				✔			

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants: Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Gasworks, coke works and other coal carbonisation plants	✓				✓									
Glass manufacturing works		✓			✓		✓				✓			
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works	✓				✓		✓							
Metal manufacturing, refining and finishing works: iron and steel works	✓			✓	✓	✓					✓			
Metal manufacturing, refining and finishing works: lead works				✓		✓					✓			
Metal manufacturing, refining and finishing works: non-ferrous metals (excluding lead works)				✓	✓	✓					✓			
Metal manufacturing, refining and finishing works: precious metal recovery works				✓			✓				✓			
Oil refineries and bulk storage of crude oil and petroleum products	✓	✓		✓	✓						✓		✓	
Photographic processing industry		✓			✓		✓				✓			
Power stations (excluding nuclear power stations)				✓		✓	✓				✓			
Printing and bookbinding works		✓			✓		✓				✓			
Pulp and paper manufacturing works				✓			✓	✓		✓	✓	✓		
Railway land						✓	✓				✓			
Road vehicle servicing and repair: garages and filling stations				✓	✓	✓	✓				✓		✓	

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants													
	Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Road vehicle servicing and repair: transport and haulage centres		✔			✔	✔	✔				✔		✔	
Sewage works and sewage farms				✔			✔			✔	✔			
Textile works and dye works	✔	✔		✔	✔		✔		✔		✔			
Timber products manufacturing works	✔	✔			✔	✔								
Timber treatment works	✔		✔	✔		✔	✔	✔						✔
Waste recycling, treatment and disposal sites: drum and tank cleaning and recycling plants		✔			✔						✔			
Waste recycling, treatment and disposal sites: hazardous waste treatment plants	✔						✔	✔	✔	✔	✔			
Waste recycling, treatment and disposal sites: landfills and other waste treatment or waste disposal sites				✔		✔	✔			✔	✔	✔		
Waste recycling, treatment and disposal sites: solvent recovery works							✔			✔				
Waste recycling, treatment and disposal sites: metal recycling sites				✔			✔				✔			

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Acetone	Acetone, also known as propanone, is used as a solvent and in the manufacture of methyl methacrylate, methyl isobytylketone and other chemicals. It is produced in the manufacture	Moderate toxicity.	Water pollutant.					
Acidity/alkalinity as indicated by measurement of pH	The pH of a soil reflects its acidity (pH<7) or alkalinity (pH>7). A pH value of 7 is neutral. Most soils tend to have an early neutral pH. Acidic industrial wastes include pyritic wastes from coal and non-metalliferous mining, china clay waste, acidic boiler ash and cinders, spent oxides, acid tars and sulphuric acid produced during the manufacture of town gas. Alkali wastes include quarry waste, fly ash, ammoniacal liquors from town gas manufacture and certain other industrial process wastes. Acidic or alkaline conditions could be found on almost any kind of site. The pH value of a soil affects the mobility and hence availability for uptake by vegetables of a number of potential soil contaminants.	Extreme pH soils are corrosive. Risk through dermal contact and ingestion.	Acidic and strongly alkaline conditions may increase mobility of contaminants.	May reduce plant growth through increasing the availability of phytotoxic metals.	Acid ground conditions may corrode building materials such as concrete, plastics, metals, and limestone.			
Aliphatic halocarbons	Chlorinated aliphatic hydrocarbons (aliphatic hydrocarbons) are used in industry for a variety of purposes. Chlorinated solvents are the most important members of this group with respect to the assessment of contaminated land and include carbon tetrachloride, chloroform, 1, 2-dichloroethane, 1, 1, 1-trichloroethane, hexachlorobut-1, 3-diene, vinyl chloride, trichloroethene and tetrachloroethene. Elevated levels of aliphatic halocarbons may originate from industrial processes, especially chemical works, coatings, printing works, cosmetic manufacturers, oil refineries, textile and dye works, timber treatment works and solvent recovery works.	Toxic. Principal risk through inhalation. Vinyl chloride is carcinogenic.	Water pollutant.	Phytotoxic.	Deleterious affect on plastic or rubbers.			

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Ammonium compounds	Elevated levels of ammonium compounds or ammonia may originate from fertilisers, explosives, plastic industries and gas works.	Although ammonia and ammonium compounds are toxic, human health is not considered a priority target.	Water pollutant. List II substance.	Phytotoxic.	Adversely affects building materials.			
Aromatic hydrocarbons	Aromatic hydrocarbons include benzene, methylbenzene, toluene and xylene. This group is often referred to as 'BTEX' compounds. Elevated levels of aromatic hydrocarbons may originate from industrial processes, for example coatings, printing works manufacture, engineering works, gas works, oil refineries and solvent recovery works.	Toxic. Principal risk through inhalation.	Water pollutant. List I substance.	Phytotoxic.	Deleterious to building materials such as plastics through mechanisms such as swelling.			
Aromatic halocarbons	This group which is also termed chlorinated aromatic hydrocarbons includes chlorobenzenes and chlorotoluenes. Elevated levels of these may be encountered at many industrial sites.	Toxic. Risk through dermal contact, inhalation and ingestion.	Water pollutant.	May accumulate in plant roots.	Can be deleterious to plastic and rubbers.			
Arsenic	Elevated levels of arsenic may originate from industrial processes, for example mineral smelting, agricultural preparations and waste disposal. Arsenic may also be associated with the ceramic, electronic, metallurgic, timber treatment, textile and tanning industries.	Toxic. Carcinogenic. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List II substance.	May reduce plant growth. Uptake can cause contamination of vegetables.		✓	✓	
Asbestos	Asbestos is a generic term for a number of naturally fibrous silicates, including crocidolite (blue), amosite (brown), and chrysotile (white asbestos).Asbestos con be found at many industrial sites due to its use as an insulation material. Heavy engineering sites, dockyards, railway engineering works, gasworks and asbestos factories appear to be especially prone to asbestos contamination.	Toxic. Carcinogenic. Principal risk through inhalation.						

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Barium	Elevated levels of barium may originate from coatings and printing inks manufacture, vehicle manufacture and glassmaking.		Water pollutant. List II substance.			✔		
Beryllium	Elevated levels of beryllium may originate from a range of industrial processes. Naturally high levels of beryllium maybe associated with natural mineralisation of certain granitic rocks, where beryl is the only common beryllium-bearing mineral.	Soluble beryllium compounds are toxic. Risk through inhalation, ingestion and dermal contact.	Water pollutant. List II substance.	Possibly phytotoxic. Uptake can cause contamination of vegetables.		✔ (but elevated levels from this source are rare)		
Boron	Elevated boron levels may be associated with engineering works, glass works, explosives manufacture, textile and dye works and timber treatment.		Water pollutant. List II substance.	Phytotoxic.		✔		
Cadmium	Elevated levels of cadmium may originate from a range of industrial processes and may occur naturally as a result of mineralisation, particularly of rocks bearing lead, zinc and copper minerals.	Toxic. Suspected carcinogen. Risk through inhalation and ingestion.	Water pollutant. List I substance.	Suspected phytotoxin. Uptake can cause contamination of vegetables.		✔		✔
Carbon dioxide	Carbon dioxide is a gas formed as a result of oxidation or combustion of organic materials or from respiration. It is normally produced together with methane from anaerobic degradation of organic materials. It may be produced by oxidation of recent sediments, coal and other carbonaceous rocks. Carbon dioxide may also be liberated from a dissolved state in groundwater and from acid water interaction with carbonate rocks such as limestone. Carbon dioxide is frequently encountered on industrial sites, especially at waste disposal (landfill) sites and coal workings. However, carbon dioxide and methane may be generated at any site where made ground (fill) is present.	Toxic and asphyxiant gas.	Dissolves readily in water.	May be phototoxic in elevated concentrations.		✔		

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Chloride	Elevated levels of chlorides may originate from a large variety of industrial processes and may occur naturally.	Human health is not considered a priority target.	Water pollutant. List II substance.	Phytotoxic at elevated concentrations.	Detrimental affect on building materials.	✔		
Chlorinated phenols	Includes monochlorophenols, dichlorophenols, trichlorophenols, tetrachlorophenols as well as pentachlorophenol and its compounds. Chlorophenols are used for a variety of domestic, agricultural and industrial purposes, especially the manufacture of herbicides/biocides. Pentachlorophenol is used as a wood preservative and maybe found at timber treatment works and chemical manufacturing plants.	Toxic. Risk through ingestion and dermal contact with dust.	Water pollutant. List I substance.	Phytotoxin.	Some chlorophenols may permeate polythene.			
Chromium	Elevated levels of chromium may originate for industrial processes, while naturally high levels may be associated with ultrabasic rocks. Chromium exists in several oxidation states, of which Cr III and Cr VI are the most stable. At soil pH of less than 5.5, CrVI is generally reduced to Cr III precipitating insoluble oxides and hydroxides. In the context of protection of human health Cr VI is the most significant state.	Cr III – low toxicity. Low risk of allergic reaction through dermal contact. Cr VI – toxic, carcinogenic. Risk through dermal contact, inhalation and ingestion.	Water pollutant. List II substance. List I substance.	Phytotoxic, although unlikely due to prevalence of Cr III in natural soil.		✔		
Copper	Elevated levels of copper may originate from a variety of industrial operations. High levels of copper may be encountered through natural geological strata and mineralisation processes. The phytotoxicity of copper is highest in acidic soils. The effect of copper, nickel and zinc may be additive.	Toxic only at elevated levels.	Water pollutant. List II substance.	Highly phytotoxic.	Corrosive to rubber.	✔	✔	
Cyanide	Cyanide can be present in soils as complex cyanides, free cyanide or as thiocyanate. Elevated levels of cyanide may originate from many industrial sites, for example gas works, plating works, heat treatment works, photography and pigment manufacture. Elevated levels of cyanide may occasionally reflect natural biochemical processes in soil.	Complex Cyanides – toxic free. Cyanides – very toxic. Thiocyanate – low toxicity.	Water pollutant. List II substance.	Phytotoxic.	Complex cyanides are reported to have detrimental effect on building materials.	✔	✔	

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Dioxins and furans	The term 'dioxins and furans' refers to a group of 210polychlorinated dibenzo-p-dioxins and furans (PCDD/PCDF)of which 17 are considered to have toxicological significance. Dioxins and furans are organic compounds produced during combustion processes and are thus present in incinerator stack emissions and emissions from burning of coal. Dioxins and furans are present as contaminants in pentachlorophenol and may therefore be found on the sites of disinfectant manufacturing works, power stations, hazardous waste disposal sites, landfill sites, solvent recovery works and timber treatment works. Most dioxins and furans released into the atmosphere ultimately accumulate in soils and sediments.	Toxic. Risk through inhalation and ingestion.	Water pollutant. List I substance.	Uptake can cause contamination of vegetables.				
Lead	Elevated levels of lead may originate from industrial land uses and from exhaust emissions from petrol vehicles. Elevated levels of lead may be encountered through natural mineralisation processes.	Toxic. Risk through inhalation and ingestion.	Water pollutant. Phytotoxic. Uptake may result in food contamination.			✔		
Mercury	Elevated levels of mercury may be present from industrial processes. Elevated levels may also be found in association with black shales and from binding in organic soils.	Toxic. Irritant. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List I substance.	Phytotoxic. Uptake can cause contamination of vegetables.		✔		✔
Methane	Methane is a flammable gas produced by the an aerobic degradation of organic material. It is frequently encountered on industrial sites, especially at waste disposal (landfill) sites, and in the vicinity of coal workings. However, methane and carbon dioxide may be generated at any site where made ground (fill) is present. Methane may be generated from the degradation of natural organic remains in recent sediments and from conversion of organic matter under the influence of elevated temperatures (e.g. in natural gas associated with coal and petroleum). Natural sources of methane which may be encountered within the UK also include swamps, marshes and fresh water lakes.	Risk of asphyxiation due to oxygen displacement.		High concentrations of methane can cause vegetation die-back.	Risk of fire and explosion.	✔		

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Nickel	Elevated levels of nickel may originate from industrial processes. Elevated levels of nickel may be found naturally, particularly in association with ultra basic rocks.	Toxic at elevated levels. Irritant. Risk through dermal contact, inhalation and ingestion.	Water pollutant. List II substance.	Phytotoxic. Uptake can cause contamination of vegetables.	Fire risk with dust or powder. Risk of toxic fumes if fires are lit on heavily contaminated sites.	✔	✔	
Nitrate	Elevated nitrate levels may be associated with sewage sludge applications to land. Although nitrate is used as a fertiliser, elevated levels in water can cause eutrophication.		Water pollutant.			✔		
Oil/fuel hydrocarbons	All industrial sites have the potential to be contaminated by hydrocarbons such as mineral oils, diesel fuel and petroleum spirits etc. Typically, these substances are found on airports, dockyards, engineering works, gas works, oil refineries, bulk storage facilities and vehicle fuelling, servicing and repairing facilities. Elevated levels of hydrocarbons may be associated with the natural geology, especially from oil source rocks such as oil shales, algal and black limestones, black shales and coals.	Toxic. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List I substance.	May reduce plant growth. Uptake can cause contamination of vegetables.	Flammable. May adversely affect building materials, especially rubber and plastics.	✔		
Organometallics	Organolead, organomercury and organotin compounds are considered the most important representatives of this group. Organotin compounds are possible soil contaminants at industrial sites such as timber treatment works and organic chemical manufacturing works. Oroganolead compounds are important anti-knock additives for gasoline additives and will often be encountered where petroleum is found. Organomercury compounds are frequently used in the preparation of other organometallic compounds.	Most, if not all, organometallic compounds are toxic to humans.	Water pollutants.	Uptake can cause contamination of vegetables.				

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Selenium	Elevated levels of selenium may originate from industrial processes, for example mining, smelting and refining of sulphide ores and coal combustion. Selenium may also be associated with the manufacture of electronic components, glass, plastics, ceramics, lubricants and waste disposal sites.	Toxic in soluble compound forms or as elemental dust. Risk through ingestion, inhalation and dermal contact.	Water pollutant. List II substance.	May be phytotoxic. Uptake can cause contamination of vegetables.		✔		
Silver	Elevated levels of silver may originate from industrial processes, natural mineralisation processes and in hydrothermal veins.	Metallic silver considered to be non toxic. Low toxic risk through dermal contact, ingestion and inhalation of silver compounds.	Water pollutant. List II substance.	May be phytotoxic.		✔		
Sulphate	Elevated levels of sulphate may be associated with colliery spoil, clinker from old power stations, rubble and slag. Elevated levels may also occur naturally in association with dark calcareous pyritic clays, marshy soils and from oil shale residues.	Not considered a priority contaminant with respect to human health.	Water pollutant. List II substance.	Can be phytotoxic.	Detrimental to building materials.	✔	✔	
Sulphide	Elevated levels of sulphide may originate from a range of industrial processes, as well as from natural mineralisation.	Not identified as a priority contaminant with respect to human health. However, can generate highly toxic hydrogen sulphide under acid conditions.	Water pollutant.	Can be phytotoxic.	Not a hazard to construction materials in the absence of oxygen and moisture. High acidity caused by biogenic oxidation to sulphate can especially affect cast iron pipework.	✔	✔	

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Sulphur	Sulphur (and its associated species, sulphates, sulphides and sulphites) may be found at many industrial sites including chemical works, railway engineering works, gas works, dockyards, iron and steel works. Free sulphur may occur naturally in sedimentary rocks, limestones and around hotsprings. Native sulphur, however, is unlikely to be encountered in appreciable quantities in the UK.	Toxic in excessive concentrations. Risk through dermal contact and inhalation. Combustible, giving rise to highly toxic sulphur dioxide.	Not deemed a priority contaminant with respect to the water environment.	Conversion to sulphide and sulphate could result in phytotoxicity.	Conversion to sulphide and sulphate could lead to attack on building materials.	✔		
Thallium	Elevated levels of thallium may originate from industrial processes and from natural mineralisation processes in some sulphide and selenium ores.	Thallium compounds maybe very highly toxic. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List II substance.	May be phytotoxic.				
Vanadium	Elevated levels of vanadium may originate from industrial processes as well as from natural mineralisation processes.	Toxic if inhaled as dust or fumes.	Water pollutant. List II substance.	Uptake can cause contamination of vegetables.		✔ (but relatively uncommon)		
Zinc	Elevated levels of zinc may originate from a range of industrial processes as well as from natural mineralisation processes. The phytotoxicity of zinc is increased in acid conditions. The effects of phytotoxicity of copper, nickel and zinc maybe cumulative.	Essentially non-toxic unless in high concentrations.	Water pollutant. List II substance.	Phytotoxic.	Fire and explosion risk from zinc dust in damp conditions.	✔	✔	

Annex 4
Qualitative risk assessment

A4.1 Context

CIRIA RP599 Contaminated Land Risk Assessment Guide, provides a guide to good practice in assessing risks from contaminated land. This distinguishes between the processes of:

- **Risk estimation** – process of estimating risk that defined receptors will suffer harm.
- **Risk evaluation** – process of evaluating need for risk management action, with regard to magnitude of risks the level of uncertainty and, if remedial action is need the objectives and broad costs and benefits.

At Phase 1 the **risk estimation** will take the form of a qualitative risk assessment, which will be entirely based on the conceptual model for each potential end-use of the site. Comments on level of uncertainty will also need to be included for each source-pathway-target linkage to allow the confidence in the assessed risks to be understood. The results of the qualitative risk assessment will allow the **risk evaluation** to be concisely described in the following chapters.

At Phase 2 (or later stages) the **risk estimation** will comprise a number of sequential steps all based on the conceptual model:

1. Interpretation of site investigation data with respect to relevant generic assessment criteria (Tier 1);
2. Interpretation of site investigation data with respect to site specific assessment criteria if appropriate (Tier 2);
3. Site specific qualitative risk assessment including input from Tier 1 and Tier 2 [this procedure].

Comments on level of uncertainty will also be required for through the interpretation of site investigation data and the qualitative risk assessment. The results of the qualitative risk assessment will allow the **risk evaluation** to be concisely described.

A4.2 Introduction

The following classification has been developed from DOE Guide to Risk Assessment and Risk Management for Environmental Protection and the Statutory Guidance on Contaminated Land (Defra September 2006). The methodology differs from that presented in Contaminated Land Risk Assessment, A Guide to Good Practice (CIRIA C552, 2001), particularly in terms of the definitions of classification of consequence, which include a consideration of immediacy of hazards.

The key to the classification is that the designation of risk is based upon the consideration of both:

a) **the magnitude of the potential consequence (i.e. severity).**
[takes into account both the potential severity of the hazard and the sensitivity of the receptor]
b) **the magnitude of probability (i.e. likelihood).**
[takes into account both the presence of the hazard and receptor and the integrity of the pathway]

A4.3 Classification of consequence

Classification	Definition	Examples
Severe	Highly elevated concentrations **likely** to result in "significant harm" to human health as defined by the EPA 1990, Part 2A, if exposure occurs. Equivalent to EA **Category 1** pollution incident including persistent and/or extensive effects on water quality; leading to closure of a potable abstraction point; major impact on amenity value or major damage to agriculture or commerce. Major damage to aquatic or other ecosystems, which is likely to result in a substantial adverse change in its functioning or harm to a species of special interest that endangers the long-term maintenance of the population. Catastrophic damage to crops, buildings or property.	Significant harm to humans is defined in circular 01/2006 as death, disease*, serious injury, genetic mutation, birth defects or the impairment of reproductive functions. Major fish kill in surface water from large spillage of contaminants from site. Highly elevated concentrations of List I and II substances present in groundwater close to small potable abstraction (high sensitivity). Explosion, causing building collapse (can also equate to immediate human health risk if buildings are occupied).
Medium	Elevated concentrations which could result in "significant harm" to human health as defined by the EPA 1990, Part 2A if exposure occurs. Equivalent to **EA Category 2** pollution incident including significant effect on water quality; notification required to abstractors; reduction in amenity value or significant damage to agriculture or commerce. Significant damage to aquatic or other ecosystems, which may result in a substantial adverse change in its functioning or harm to a species of special interest that may endanger the long-term maintenance of the population. Significant damage to crops, buildings or property.	Significant harm to humans is defined in circular 01/2006 as death, disease*, serious injury, genetic mutation, birth defects or the impairment of reproductive functions. Damage to building rendering it unsafe to occupy e.g. foundation damage resulting in instability. Ingress of contaminants through plastic potable water pipes.
Mild	Exposure to human health **unlikely** to lead to "significant harm". Equivalent to **EA Category 3** pollution incident including minimal or short lived effect on water quality; marginal effect on amenity value, agriculture or commerce. Minor or short lived damage to aquatic or other ecosystems, which is unlikely to result in a substantial adverse change in its functioning or harm to a species of special interest that would endanger the long-term maintenance of the population. Minor damage to crops, buildings or property.	Exposure could lead to slight short-term effects (e.g. mild skin rash). Surface spalling of concrete.
Minor	No measurable effect on humans. Equivalent to insubstantial pollution incident with no observed effect on water quality or ecosystems. Repairable effects of damage to buildings, structures and services.	The loss of plants in a landscaping scheme. Discoloration of concrete.

* For these purposes, disease is to be taken to mean an unhealthy condition of the body or a part of it and can include, for example, cancer, liver dysfunction or extensive skin ailments. Mental dysfunction is included only insofar as it is attributable to the effects of a pollutant on the body of the person concerned.

A4.4 Classification of probability

(only applies if there is a possibility of a pollutant linkage being present)

Category	Definition	Examples
High likelihood	**There is pollutant linkage and an event would appear very likely in the short-term and almost inevitable over the long-term, or there is evidence at the receptor of harm or pollution.**	*a) Elevated concentrations of toxic contaminants are present in soils in the top 0.5m in a residential garden.* *b) Ground/groundwater contamination could be present from chemical works, containing a number of USTs, having been in operation on the same site for over 50 years.*
Likely	**There is pollutant linkage and all the elements are present and in the right place which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short-term and likely over the long-term.**	*a) Elevated concentrations of toxic contaminants are present in soils at depths of 0.5-1.0m in a residential garden, or the top 0.5m in public open space.* *b) Ground/groundwater contamination could be present from an industrial site containing a UST present between 1970 and 1990. The tank is known to be single skin. There is no evidence of leakage although there are no records of integrity tests.*
Low likelihood	**There is pollutant linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a long period such an event would take place, and is less likely in the shorter term.**	*a) Elevated concentrations of toxic contaminants are present in soils at depths >1m in a residential garden, or 0.5-1.0m in public open space.* *b) Ground/groundwater contamination could be present on a light industrial unit constructed in the 1990s containing a UST in operation over the last 10 years – the tank is double skinned but there is no integrity testing or evidence of leakage.*
Unlikely	**There is pollutant linkage but circumstances are such that it is improbable that an event would occur even in the very long-term.**	*a) Elevated concentrations of toxic contaminants are present below hardstanding.* *b) Light industrial unit <10 yrs old containing a double-skinned UST with annual integrity testing results available.*

Note: A pollution linkage must first be established before probability is classified. If there is no pollution linkage then there is no potential risk. If there is no pollution linkage then there is no need to apply tests for probability and consequence.

For example if there is surface contamination and a major aquifer is present at depth, but this major aquifer is overlain by an aquiclude of significant thickness then there is no pollution linkage and the risks to the major aquifer are not assessed. The report should identify both the source and the receptor but state that because there is no linkage there are no potential risks.

A.4.5 The classification of risk

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability (Likelihood)	**High likelihood**	Very high risk	High risk	Moderate risk	Low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

A4.5.1 Description of the classified risks

Very high risk
There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without remediation action OR there is evidence that severe harm to a designated receptor is already occurring. Realisation of that risk is likely to present a substantial liability to be site owner/or occupier. Investigation is required as a matter of urgency and remediation works likely to follow in the short-term.

High risk
Harm is likely to arise to a designated receptor from an identified hazard at the site without remediation action. Realisation of the risk is likely to present a substantial liability to the site owner/or occupier. Investigation is required as a matter of urgency to clarify the risk. Remediation works may be necessary in the short-term and are likely over the longer term.

Moderate risk
It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely, that the harm would be relatively mild. Further investigative work is normally required to clarify the risk and to determine the potential liability to site owner/occupier. Some remediation works may be required in the longer term.

Low risk
It is possible that harm could arise to a designated receptor from identified hazard, but it is likely at worst, that this harm if realised would normally be mild. It is unlikely that the site owner/or occupier would face substantial liabilities from such a risk. Further investigative work (which is likely to be limited) to clarify the risk may be required. Any subsequent remediation works are likely to be relatively limited.

Very low risk
It is a low possibility that harm could arise to a designated receptor, but it is likely at worst, that this harm if realised would normally be mild or minor.

No potential risk
There is no potential risk if no pollution linkage has been established.

Definitions	
Hazard	A property or situation which in certain circumstances could lead to harm. [The properties of different hazards must be assessed in relation to their potential to affect the various different receptors].
Risk	A combination of the probability or frequency of the occurrences of a defined hazard **AND** the magnitude of the consequences of that occurrence.
Probability	The mathematical expression of the chance of a particular event in a given period of time [e.g. probability of 0.2 is equivalent to 20% or a 1 in 5 chance].
Likelihood	Probability; the state or fact of being likely.
Consequences	The adverse effects (or harm) arising from a defined hazard which impairs the quality of the environment or human health in the short or longer term.
Pollution linkage	An identified pathway is capable of exposing a receptor to a contaminant and that contaminant is capable of harming the receptor.

Annex 5
Risk assessment models

A5.1 Choosing the model

The majority of quantitative risk assessment models concentrate on examining variations in the pathway from the source to the receptor. It is important to ensure the conceptual model of your site is consistent with the risk assessment model being used. For instance if your site has contamination in the soil below the groundwater table a model examining migration of contaminants from the near surface soil through an unsaturated zone below impacting the groundwater is inappropriate. The pathways and conceptual model for some commonly used models are described briefly later in these notes. An understanding of the models is essential both when entering data and also when interpreting the results. The ability of the model to examine very specific feature such as fractured flow in chalk or free product is not necessarily described but is often an important consideration.

A5.2 Types of model

Models are generally targeted to examine a particular receptor in land and water – these are generally either Human Health or a Controlled Water. Some models such as BP RISC and RBCA can look at both these aspects although they are generally (but not always) calculated on separate runs.

There are two types of model, deterministic models and probabilistic models:

- Deterministic models use a single equation to relate the exposure at the source with that at the receptor. These are relatively simple calculations which are suitable for use where the data is limited. In using these models conservative assumptions should generally be made, although this means the answers can be overly conservative.
- Probabilistic (or stochastic) models treat the data in a more statistical way and thus instead of providing a single number output they provide a distribution. These models overcome the overly conservative outputs of deterministic models. However, they require a lot more data to be used appropriately.

In addition models can often be run in either of two modes:

- Forward calculations which use known concentrations in the subsurface to predict impacts at receptors;
- Back-calculations which use acceptable concentrations or doses at the receptor to predict acceptable concentrations in the subsurface.

The choice of computer model and mode to run it in will depend on the complexity of the conceptual model being considered. Quantitative risk assessments therefore range from the simple to the complex, but to ensure consistency of approach all assessments need to be completed and/or reviewed by staff experienced in using risk assessment packages, in addition to technical review.

A5.3 Typical data requirements

Data requirements vary with the complexity of the conceptual model and also with the computer model selected, but the types of information listed overleaf would typically be used in an assessment.

Typical Parameters for Human Health Risk Quantitative Modelling	Data source
Depth, extent and concentrations of contaminants in unsaturated, saturated, vapour, dissolved and or free phase source	Site Data
Geological properties (porosity, soil organic matter (SOM), air and water content) for source layer and all above strata	Direct from site data or estimated from good geotechnical descriptions
Hydrogeological properties (groundwater levels, gradient, hydraulic conductivity) for source layer and all above strata	Direct from site data (hydraulic conductivity occasionally estimated)
Use of the site – current and proposed	Site Data
Amount of hard cover – current and proposed	Site Data
Building parameters (no. of air exchanges, fraction of cracks etc.) – current and proposed	Direct from site data or estimated from description of buildings
Exposure parameters (body weight, exposure duration, exposure frequency exposure rates, times and skin areas etc.)	Exposure databases including CLEA, BP RISC, RBCA
Chemical properties of contaminants including toxicological parameters and degradation rates (if published)	Chemical databases including CLEA, BP RISC, RBCA

Typical Parameters for Risk to Controlled Waters Quantitative Modelling	Data source
Detailed sensitivity information including local and regional aquifer hydrogeology and chemistry	Additional Phase 1 information
Detailed receptor information including pumping rates, screen depths and use for abstraction wells, and low flow and uses of surface water	Additional Phase 1 information
Depth, extent and concentrations of contaminants in unsaturated, saturated, vapour, dissolved and or free phase source	Site Data
Geological properties (porosity, fraction of organic carbon (FOC), air and water content) for source layer and all potentially impacted underlying strata	Direct from site data or estimated from good geotechnical descriptions
Hydrogeological properties (groundwater levels, gradient, hydraulic conductivity) for source layer and all potentially impacted underlying strata	Direct from site data (hydraulic conductivity occasionally estimated)
Amount of hard cover and recharge information – current and proposed	Site Data and additional Phase 1 information
Chemical properties of contaminants including toxicological parameters and degradation rates (if published)	Chemical databases including CLEA, BP RISC, RBCA

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
Risc v4.03 (BP)	Soil, groundwater, surface water.	Humans (site users, construction workers, trespassers, neighbours, swimmers). Groundwater and surface water.	Soil ingestion, dermal contact. Vegetable ingestion (uptake from soil and irrigation water). Volatilisation from soil, transport to indoor air and outdoor air. Volatilisation from groundwater to indoor air. Ingestion from private water supply. Ingestion, inhalation and dermal contact (in shower, garden sprinkler). Ingestion and dermal contact (swimmers).	Leaching to groundwater from unsaturated zone. Leaching to groundwater from saturated zone. Lateral transport of contaminants dissolved in groundwater.	*All Pathways* Not based on UK methodologies. *Human Health* Default receptor parameters and exposure scenarios database do not include UK data – can be modified. Default chemical parameters database does not include UK toxicity data – can be modified. Probabilistic option is different to UK approach.	*All Pathways* Allows simultaneous calculation for TPH fractions. Extensive database of physical chemical properties. *Human Health* Includes a volatilisation from groundwater model.	Can model risk from free phase, but not transport of free phase.
CONSIM 2 (Golder Associates and EA)	Soil, groundwater, soakaway.	Groundwater, soakaway.	Not applicable.	Leaching to groundwater from unsaturated zone. Migration to groundwater from saturated zone. Lateral transport of contaminants dissolved in groundwater.	No 'backwards' calculation to predict remedial targets – can be done by iteration.	Methodology consistent with UK approach. Probabilistic model. Option to model in fractured rock. Extensive database of contaminant properties.	Can model risk from free phase, but not transport of free phase.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
CLEA UK *beta* (EA) *Note: Final version not currently available – likely to change.*	Soil.	Humans (site users).	Soil ingestion, dermal contact. Vegetable ingestion (uptake from soil). Volatilisation from soil, transport to indoor air and outdoor air.	Not applicable.	Only models one exposure scenario in each run. Run time typically slow. No option to consider bioavailability.	Is the most consistent with the UK approach. CLEA standard exposure scenarios included as default settings. Most parameters can be adjusted to allow site specific risk variation. No charge for use.	No.
RCLEA	Soil.	Humans (site users).	Whole body irradiation, irradiation through dermal contact. Vegetable ingestion (uptake from soil), transport to indoor air and outdoor air.	Not applicable.	Point sources cannot be taken into account. Application to real sites not yet in public domain.	Uses the same basic exposure assumptions as CLEA. Simple to use in generic format. Can be used in site specific format to create new land uses. No charge for use.	Not applicable.
Remedial Targets Methodology 2006 (EA)	Soil, groundwater.	Groundwater, surface water.	Not applicable.	Leaching to pore water in unsaturated zone. Transport of pore water to saturated zone. Lateral transport of dissolved contaminants in aquifer.	Only models one contaminant at a time. No database of contaminant properties. Not ideal for modelling transport in fractured rock. Not probabilistic.	Methodology is UK approach. Backward calculation to predict remedial thresholds. No charge for use.	Can model risk from free phase, but not transport of free phase.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
RAM (ESI)	Soil, groundwater.	Groundwater, surface water.	Not applicable.	Leaching to pore water in unsaturated zone. Transport of pore water to saturated zone. Lateral transport of dissolved contaminants in aquifer. Can be customised for site specific pathways.	Requires separate add-in for probabilistic functionality.	Methodology based on UK approach. Multiple contaminants can be modelled in one run. Can model flow in multiple hydrogeological units.	Can model risk from free phase, but not transport of free phase.
GasSim (Golder Associates and EA)	Landfill waste.	Off-site soil gas. Off-site humans (chronic risk). Flares/gas plant. Atmosphere.	Generation of gas from waste, migration through cap and liner. Lateral migration of gas and vapour within unsaturated zone. Soil and derived dust ingestion and dermal contact. Dust inhalation, indoor and outdoor. Vapour inhalation, indoor and outdoor. Vegetable ingestion (uptake from soil).	Not applicable.	Not primarily intended as a contaminated land assessment tool. Requires tonnage inputs of different waste types, which may not be available for historic sites. Users require knowledge of landfill engineering and complex air dispersion modelling.	Methodology is UK approach. Includes four standard CLEA exposure scenarios.	Not applicable.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
RAM (ESI)	Soil, groundwater.	Groundwater, surface water.	Not applicable.	Leaching to pore water in unsaturated zone. Transport of pore water to saturated zone. Lateral transport of dissolved contaminants in aquifer. Can be customised for site specific pathways.	Requires separate add-in for probabilistic functionality.	Methodology based on UK approach. Multiple contaminants can be modelled in one run. Can model flow in multiple hydrogeological units.	Can model risk from free phase, but not transport of free phase.
GasSim (Golder Associates and EA)	Landfill waste.	Off-site soil gas. Off-site humans (chronic risk). Flares/gas plant. Atmosphere.	Generation of gas from waste, migration through cap and liner. Lateral migration of gas and vapour within unsaturated zone. Soil and derived dust ingestion and dermal contact. Dust inhalation, indoor and outdoor. Vapour inhalation, indoor and outdoor. Vegetable ingestion (uptake from soil).	Not applicable.	Not primarily intended as a contaminated land assessment tool. Requires tonnage inputs of different waste types, which may not be available for historic sites. Users require knowledge of landfill engineering and complex air dispersion modelling.	Methodology is UK approach. Includes four standard CLEA exposure scenarios.	Not applicable.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
RISC-HUMAN v3.2 (Van Hall Insituut)	Soil, groundwater, sediment, surface water.	Humans (site users).	Soil ingestion, dermal contact. Volatilisation from soil, transport to indoor air and outdoor air. Inhalation of soil dust. Vegetable uptake. Volatilisation from groundwater, transport to indoor air. Ingestion from private water supply (direct or from permeation of pipes). Inhalation and dermal contact (in shower). Ingestion of water and suspended matter, dermal contact (swimmers). Ingestion of fish, meat and dairy produce. Leaching from sediment in to surface water (see related pathways above).	Not applicable.	Default chemical parameters database does not include UK physical toxicity data – can be modified. Default receptor parameters and exposure scenarios database do not include UK data – can be modified. Not based on UK methodologies.	Can create sub-sites with different land uses. Sophisticated vapour model with a number of conceptual models.	Models LNAPL vapour risk from free phase in unsaturated zone.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
SNIFFER (Scottish & Northern Ireland Forum for Environmental Research)	Soil.	Humans (site users).	Soil ingestion. Vegetable uptake. Volatilisation from soil to indoor and outdoor air.	Not applicable.	Does not include dermal contact pathway. Simple vapour model requires calculation of dilution factor to be consistent with UK approach. Only models one contaminant at a time. No database of chemical parameters.	Includes bioaccessibility option. Methodology is based on UK approach.	No.

A5.3.1 Web Addresses for Further Information and Downloads

Model	Web address
Risc v4.03 (BP)	www.bprisc.com www.groundwatersoftware.com/software/risk/risc/risc.htm
CONSIM 2 (Golder Associates and EA)	www.consim.co.uk
CLEA UK beta (EA)	www.environment-agency.gov.uk/subjects/landquality/113813/672771/1166367/1166388/?version=1&lang=_e
Remedial Targets Methodology 2006 (EA)	www.environment-agency.gov.uk/subjects/landquality/113813/887579/887905/?lang=_e
RAM (ESI)	www.esinternational.com/downloads/index.php
GasSim (Golder Associates and EA)	www.gassim.co.uk
LandSim (Golder Associates and EA)	www.landsim.co.uk
RBCA Toolkit – chemical releases (GSI International)	www.gsi-net.com/software.asp
RISC-HUMAN v3.2 (Van Hall Insituut)	www.risc-site.nl/index.html?riscmainFrame=download.htm
SNIFFER (Scottish & Northern Ireland Forum for Environmental Research)	www.sniffer.org.uk

Annex 6
Risk assessment, perception and communication

A6.1 Background

The management of contaminated land is founded upon a risk based approach. Such an approach is systematic, objective and should provide a scientifically sound, robust and defensible basis on which the options for mitigating such risks can be considered. The scientific and technical aspects concerned with this assessment are generally well known and understood by the specialist parties involved. However, perhaps what is less well recognised, particularly by problem holders and their consultants, is the need for and mechanisms of, communication with all stakeholders, including non specialists such as the public, in this process.

A6.2 Principles of stakeholder dialogue

It is important to recognise that when contaminated land projects are initiated, an appropriate degree of attention must be given to dialogue with stakeholders. Such a dialogue must be an inclusive process involving all groups who may have an interest in the outcome of the project. This may run counter to the instincts of some problem holders, but experience has shown that a properly conducted process, involving all stakeholders (including those who are often deliberately excluded) will often maximise the “buy-in” of stakeholders and thus ensure that the solutions arrived at will be supported and will survive over the long-term.

The principles of effective stakeholder dialogue can be summarised as:

- Identifying who all the stakeholders are;
- Recognising why you are engaged in the process;
- Clearly defining what you are trying to achieve; and
- Determining how you will attain those objectives.

A6.3 The involvement of stakeholders

There are several ways in which information between stakeholders can be obtained and exchanged. Each of these has their own particular characteristics and thus influences the potential outcome. It is therefore important that before engaging with stakeholders, consideration must be given to what all parties are likely to want to come away with from any such involvement. So for example, if the problem holder determines that they want only to provide information to stakeholders they may choose to provide limited information by means of a simple announcement. They may not wish to gather or listen to any views of the other stakeholders. The results of such “involvement” are likely to depend upon degree of authority of the problem holder and the perceptions of that authority by stakeholders. However, there is a real possibility that stakeholders may react adversely to such a one-way communication and positions will become polarised as a result.

Therefore at the commencement of the process it is important to be clear about what objectives there are for both the problem holder and the various stakeholders. This will then enable determination of what type of engagement is most appropriate. So for example, awareness raising or information giving will tend to be one way communication with specific objectives (e.g. of simply providing the results of a decision or explaining some issue to change prevailing attitudes). Two-way communication becomes an essential element where engagement involves consultation, involvement or partnership. These processes involve an increasing level of engagement with stakeholders.

There are occasions however when serious consideration must be given to not entering into a dialogue with stakeholders. For example, if a decision that cannot be changed has been made, a 'consultation' process will merely raise expectations and will inevitably disappoint. Similarly if there is no time available, no commitment from senior management, or if key stakeholders will not attend, there is no real prospect of success for a process of 'dialogue'.

In 2003 the government (HM Treasury and Cabinet Office) listed five principles for good risk management, namely:

- Openness and transparency – make public; risk assessment, the decision making process, admission of mistakes.
- Involvement – actively involve significant stakeholders, two-way communication at all stages, clarification through open discussion, balance conflicting views.
- Act proportionately and consistently – action to be proportionate to protection needed and targeted to risk. Consistent approach to risk. Precautionary principle. Revisit decisions as knowledge changes.
- Evidence based decisions – consider all evidence and qualify before making decisions. Seek impartial/informed advice. Absence of evidence is not absence of threat.
- Responsibility – those that impose risk also take responsibility for control and consequences of inadequacy. Where feasible give individuals choice (where others not exposed to disproportionate risk/cost). Identify where responsibility lies.

A6.4 The risk assessment process

The process of risk assessment in contaminated land projects (as described in the main text of R&D66: 2008) is generally well developed, understood and delivered by the many specialists involved in the area. The use of simple tools has improved consistency in qualitative assessment (see R&D66: 2008 Section 1.7) and the continuing development of numerical systems (see R&D66: 2008 Section 2.8 and Annex 4) has lead to widespread acceptance (at least in the industry) of the value and validity of quantitative risk assessments.

However, there is a common failing within problem holders and their consultants in understanding that this stepwise process of risk assessment, which to some appears straightforward, and scientifically robust, is not so logical to many other stakeholders. It does appear to be a commonly adopted (and wrong) position that because the 'expert' assessment shows the level of risk to be 'acceptably low' this should be automatically and universally accepted by other stakeholders (who are necessarily less 'expert'). Such a position fails to recognise that factors other than the technical assessment can have a significant influence on people's perception of risk. In fact "Perception is Reality" [Sniffer 1999].

A6.5 Risk perception

A6.5.1 General

People with different social, economic and cultural backgrounds living in different places will perceive risks in different ways which reflect their own particular knowledge and their environment. That is, people's response to a particular hazard depends upon their perception of the hazard and their knowledge/awareness of both themselves, and "society" to deal with that hazard.

The risk perceived by people may also reflect; the potential for the hazard to be controlled, the potential for catastrophe and their "dread" of that hazard. So for example if a site has radioactive contamination associated with it, the perceived level of risk is likely to be high, reflecting peoples dread of radioactivity. Such dread reflects for example the known effects of fallout from nuclear explosions and visions of Hiroshima. The less familiar people are with a hazard and the less control they have over the potential for exposure, the greater the perception of the risk.

A6.5.2 Voluntary risk

Perception may also be affected by whether or not exposure to the risk is voluntary (when people are more prepared to accept risk, or their perception of such voluntary risk is less than when they have no choice about the matter). For example the risk of knowingly ingesting known carcinogens directly into your lungs several times a day is perceived to be lower by smokers because this activity is undertaken voluntarily. This must be contrasted for example with the circumstances where residents are told that they have been living on the site of historic contamination where for example polyaromatic hydrocarbons are present at concentrations above background levels. The combination of the dread associated with the term 'carcinogenic' and the involuntary nature of the exposure will serve to increase the perception of this risk well above the level of any technical assessment.

A6.5.3 Expert assessment

Risk assessment carried out by experts can not be "absolute" because:

- Experts themselves may be biased or motivated by their own values/self interests; and
- This expert assessment takes no account of the beliefs of 'the public'.

What often takes place in the contaminated land debate is that the expert defines the objective risk and then tries to align the perception of the public and the regulator with this version of reality (or "the truth"). As described above, often no recognition is made by the expert those factors other than the technical estimation of risk influences how people perceive and behave in the face of particular hazards.

Decisions taken with regard to a particular risk are not driven only by calculation of probability. For example, relative estimates of risk have not figured at all in the debate about genetically modified organisms. A major factor in the opposition of this technology is a lack of trust in those "in control" of the technology or regulating the risks. It has also been shown that an important element in the perception of risk is the particular personal disposition of an individual – i.e. people perceive risk as more or less difficult depending on the way in which they see the world (e.g. whether they are fatalists, egalitarians etc.).

This complex series of issues which influence the perception of risk must therefore be taken into account in order to develop an effective means of communicating that risk. The key is in the risk – benefit communication which enables people to make an informed choice regarding exposure to a particular hazard. Risk communication should not be seen as top down (i.e. expert to public) but as a constructive dialogue between all parties.

A6.5.4 The media

The media also play an important role in the public perception of risk. This is because the media are likely to influence judgements about risk much more than people's objective assessment of the 'facts'. The media may or may not directly influence what someone thinks, but the amount of coverage given to an issue can make issues appear significant/important. Social amplification of risks may also occur when an event associated with a hazard interacts with the psychological, social and cultural make up of people, raising (or reducing) the perception of risk and affecting how people then behave. Some researchers have noticed that in some cases, increased coverage actually leads to an increase in factual information (and thus people's ability to make "proper" risk judgements). Conversely, the use of headlines and photographs together with the emotional tone of the article can disproportionately affect the perception of the hazard.

A6.5.5 Trust

The success or otherwise of communications regarding risk involves the consideration of both:

- the message about the hazard itself (its likelihood, potential costs and benefits in mitigation);
- the trust people have in those giving the message.

Failure in risk communication is usually caused by public distrust in both the makers of policy, and officers of companies/regulatory bodies, due to problems of credibility. ["They would say that wouldn't they".] Experts presenting technical numerical information about risk which discounts the public perception of that risk as 'irrational' become distrusted by the public who view them as arrogant and lackeys of vested interests. It is important to recognise that it is much easier to loose someone's trust than to build it. Once trust is lost, it is very difficult to regain. The key elements in trust are the competence/credibility of the people putting the argument. People's perception of such a level of trust is often significantly influenced by the track record of the organisation/expert. For example, that over the last 50 years or so, there has been a general decline in the trust of scientists due to matters such as DDT, thalidomide, Three Mile Island, Chernobyl, BSE etc.

However, the potential hazards associated with contaminated land and their associated risks can also be used by objectors to particular schemes/projects. Such groups of people also have a vested interest, often summarised as "not in my backyard". Land contamination and the potential risks to people's health (often the new residents who will live in the proposed new housing development) can be cited by objectors as one of the elements in their opposition to a proposed development scheme.

Experience has shown that to those involved in the assessment/redevelopment of contaminated land, importance must be attached to both the technical assessment of risk and also to the concerns of all stakeholders and their perceptions.

A6.6 Conclusions

- Risk assessment is not just a scientific calculation. Perception is and must be the reality.
- All parties must get it right at the beginning (i.e. both the assessment of risk and the communication strategy).
- Stakeholder concerns are "real" – their perceived risks cannot just be discounted on the basis of some "scientific" judgement.
- It is important that all professional parties are credible and trustworthy.
- These parties must be able to properly communicate the risks that face people and the environment to all of the stakeholders involved.

A6.7 Further reading

- Dialogue for Sustainability [Training Manual]. Environment Council, 2002.
- Guidelines for environmental risk assessment and management. DEFRA, 2000.
- Communicating understanding of contaminated land. Sniffer, 1999.
- Risk communication, a guide to regulatory practice. Ilgra, 1998.
- Risk: Analysis, perception and management. Royal Society, 1992.
- Risk and modern society. Lofstedt and Frewer, 1991.
- Risk communication. Brownfield Briefing, December 2006.

Annex 7
Waste management

A7.1 Waste management framework

A7.1.1 Background

"Waste" is defined in Article 1 (a) of the Waste Framework Directive (Ref 1) as "any substance or object…which the holder discards to intends or is required to discard". It is the responsibility of the producer of a substance or object to decide whether or not they are handling "waste". The definition of "waste" is important. If a material is considered waste, then the producer/developer/designer must consider its waste management licensing requirements. Any such requirements are likely to have a significant impact on the design of the earthworks/construction both in terms of time and cost. Furthermore, failure to comply with waste management legislation can result in prosecution. This Annex describes the regulatory requirements and summarises the guidance available for the different options and scenarios often encountered in brownfield re-development.

A number of elements of U.K. policy and guidance with respect to waste are currently at a draft or interim stage. In particular, in 2006 the Environment Agency published a guide to those involved in construction (including remediation) on greenfield and brownfield sites to assist in the determination of whether or not "waste" is being handled, and any associated legal obligations (Ref 2). In addition, a proposed Code of Practice [CoP] (Ref 3) is currently in draft form and is subject to public consultation. The Environment Agency proposes to issues new guidance following any adoption of any Final CoP. It is the intention of the NHBC and the authors to up-date this Annex once the CoP and any associated Environment Agency guidance is published.

This Annex has reported the current position and has not anticipated any particular outcome. Accordingly, practitioners are advised to determine whether final version of guidance etc. is available and also to consult with the relevant Environment Agency waste officer at the earliest opportunity.

A7.1.2 Regulatory framework and guidance

The following regulations apply to the management of waste with respect to soils arising from construction and contaminated sites:

- Waste Framework Directive (Ref 1);
- Hazardous Waste Directive (Ref 4).

The Waste Framework Directive (Ref 1) sets out a number of definitions including terms such as 'waste', 'recovery' and 'disposal'. The Hazardous Waste Directive (Ref 4) provides a precise and uniform European-wide definition of Hazardous Waste with the objective of ensuring correct management and regulation of such waste. The Revised European Waste Catalogue (Ref 5) is a catalogue of all wastes, grouped according to generic industry, process or waste type.

The following UK legislation implements these European Directives and are particularly relevant to brownfield redevelopment and spoil arisings. [See the Reference list to this Annex for the full titles.]:

- The Environmental Protection Act 1990 (Ref 6);
- The Control of Pollution Act 1989 (Ref 7);
- The Waste Management Licensing Regulations 1994 (Ref 8);
- The Controlled Waste Regulations 1991 (Ref 9);
- The Hazardous Waste Regulations 2005 (Ref 10);
- The List of Waste Regulations 2005 (Ref 11).

From 6th April 2008, the Environmental Permitting Regulations (Ref 12) came into force. Environmental Permits replace the system of waste management licensing in Part II of the

Environmental Protection Act (Ref 6) and bring together the Waste Management Licensing Regulations 1994 and the Pollution Prevention Control (England and Wales) Regulations 2000 into one streamlined regime.

A7.1.3 Site waste management plans

The Site Waste Management Plans Regulations 2008 were introduced in England in April 2008 and are likely to follow in Wales). The aims of these Site Waste Management Plans (SWMPs) are; to reduce the amount of waste produced on construction sites and to help prevent fly tipping (Ref 13). Site Waste Management Plans must detail the amount and type of waste that a construction or demolition site will produce and describe how it will be reused, recycled or disposed of. The plan is then up-dated during the construction process to record how the waste is managed and to confirm the disposal of any materials that cannot be reused or recycled.

In Scotland and Northern Ireland SWMPs are not yet proposed as a legal requirement. However some companies and local authorities are requiring their contractors to implement SWMPs to demonstrate commitment to sustainability.

SWMPs are required for any construction project costing more than £300,000. They require all those responsible for projects to forecast how much of each type of waste they will produce and to record how much of it will be re-used or recycled.

A7.2 Re-use of materials on-site

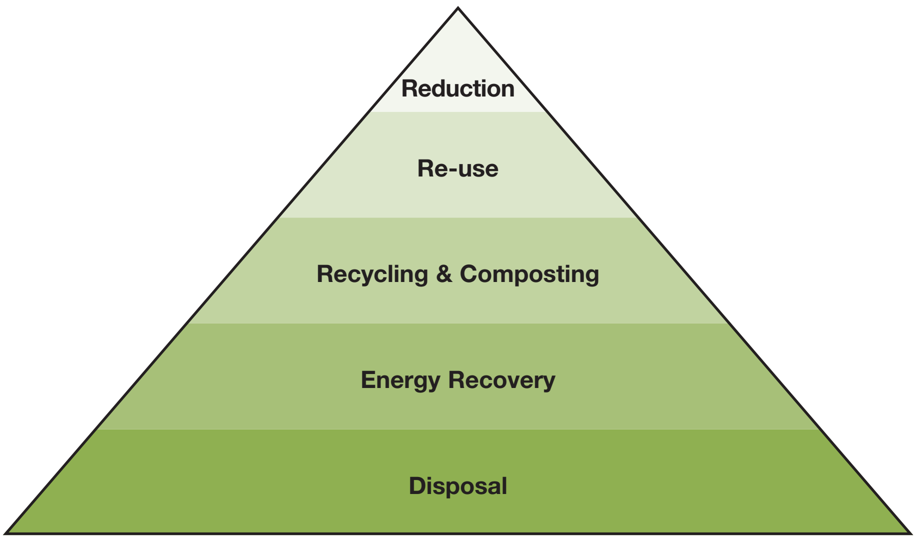
A7.2.1 General

The waste management hierarchy informs decisions on the management of waste including soils arising from construction work on development sites (Ref 14). The overall aim of the policy is to move activity higher up the hierarchy, reflecting higher levels of sustainable resource and waste management.

The definition of waste and its application to site-won materials is key to determining licensing requirements and potential re-use options, as discussed below.

The Environment Agency's protocol on the re-use of site-won materials is outlined below.

The Waste Management Hierarchy



A7.2.2 Uncontaminated soils

Aggregate materials produced from inert waste (i.e. crushed concrete, building materials etc.) in accordance with the WRAP quality protocol (Ref 15) should not be classified as waste and therefore can be re-used on-site without an Environmental Permit (previously waste management licence).

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of uncontaminated soils on-site. Further guidance regarding the re-use of uncontaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.2.3 Contaminated soils

The current Environment Agency policy is that contaminated soils become "waste" once excavated and therefore an Environmental Permit (previously waste management licence) is normally required to cover their treatment and/or redeposit.

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of contaminated soils on-site. Further guidance regarding the re-use of contaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.2.4 Waste management license exemptions

Where soils are regarded as "waste" by the Environment Agency, their re-use on-site may take place under an "exemption" from Environmental Permitting (waste management licensing). In order for an activity to qualify for an exemption, the re-use must be carried out:

- Without endangering human health or the environment;
- Without risk to air, soil, plants or animals;
- Without causing nuisance through noise and odours; and
- Without adversely affecting the countryside or sites of special scientific interest.

Exemptions are granted under the Environmental Permitting Regulations (Ref 12) [previously Schedule 3 of the Waste Management Licensing Regulations (Ref 16)]. Further guidance is available at www.environment-agency.gov.uk/commondata/acrobat/exemption_changes_2008963.pdf

In general the following paragraphs are applicable to construction on contaminated land:

- Paragraph 9 – Land Reclamation;
- Paragraph 13 – Manufacture of construction and soil materials;
- Paragraph 19 – Storage and use of waste for construction; and
- Paragraph 24 – Storage of bricks, tiles or concrete (crushing and treatment was previously covered under WML but this is now covered by the Part B authorisation).

Exemptions are often subject to conditions which describe the type and quantity of material to be processed, the methods of disposal or recovery and pollution control measures. If the soil arisings remain classified as Hazardous Waste, exemption will not be granted.

Most exemptions with respect to contaminated land/construction sites are granted with respect to paragraphs 9 and 19. These exemptions restrict the volumes of soils being used (paragraph 9 stating this applies where volumes do not exceed 20,000m^3 per hectare). Both exemptions require input from the planning authorities. This may comprise specific planning permission, a note to say the existing planning conditions are suitable for the exemption application or a note to say no planning permission is needed. The Environment Agency will not grant an exemption without such written confirmation from the local authority.

Exemptions cost approximately £500-600 (administration fees) and the Environment Agency recommend that a period of 35 days is allowed for in order to gain an exemption. The Environment Agency will either send a confirmation of the exemption or notification of refusal. There is no appeal process.

A7.3 Off-site disposal

A7.3.1 General

For soils requiring off-site disposal (or on-site re-use if the soils are classified as "waste"), classification into one of the three waste categories is required [Hazardous; Non-Hazardous; Inert]. Chemical analytical data (soil and leachate) must be assessed with reference to the:

1. Framework for Classification (Ref17) [Note: It is understood that the Environment Agency plans to withdraw this document]; and
2. Technical Guidance WM2 (Ref18).

In addition, analysis for Waste Acceptance Criteria (WAC) must be carried out related specifically to landfill acceptance (Ref 19).

A7.3.2 Waste classification

Many practitioners have developed a waste classification spreadsheet that uses the threshold values and approaches described in the references above. The concentrations of contaminants are compared against these thresholds for fourteen different hazards (H1 to H14). Examples of the hazards include H14 – Ecotoxicity, H8 – Corrosivity, H10 – Toxicity for Reproduction etc. The majority of these hazards require assessment of more than one risk phrase. Many risk phrases are associated with more than one contaminant type. For example, R36-38 requires the assessment of data with respect to Xylene, dimercury dichloride, calcium sulphate and copper sulphate.

A7.3.3 Hydrocarbon contaminated soils

Where soils have been initially classified as Hazardous due to elevated concentrations of hydrocarbons, the type of hydrocarbon contamination should be determined. Different threshold concentrations can be applied to certain types of hydrocarbon contamination. Soils that would be categorised as Hazardous using the standard (0.1%) threshold may be suitable for disposal at a Non-Hazardous landfill if the type of hydrocarbon contamination is known (e.g. Diesel has a threshold of 1%). Consideration of certain PAH concentrations is also required. Guidance on the classification of oily waste was published by the Environment Agency in 2007 (Ref 20).

A7.3.4 Other contaminated soils

The results of the waste classification assessment can be used to determine the following:

- whether the soils represent a hazard to the environment and their potential for re-use on-site; and
- whether soils destined for disposal off-site would be disposed of at a Hazardous or Non-Hazardous/Inert Waste disposal facility.

The conservative assumption in WM2 is that all contaminants are present in their most hazardous form (e.g. all arsenic is assumed to be present as arsenic trioxide etc.). Made Ground is commonly classified as Hazardous due to potential ecotoxic effects (H14) by virtue of elevated concentrations of heavy metals (most commonly arsenic, lead, nickel and zinc). However, it is not possible to undertake speciation of inorganic determinands (i.e. determine whether arsenic is present as arsenic trioxide, or more common form such as arsenic pyrite) using standard laboratories. In order to examine this further consideration should be given to the data which could be obtained from leachability analysis and direct toxicity testing.

Leachability data
Soil samples should be scheduled for leachability testing and the results screened against Environmental Quality Standards (EQSs) (Ref 21). If a significant number of samples record exceedences of the EQS for any of the metal determinands (most commonly arsenic, lead, nickel and zinc) responsible for the H14 classification, direct toxicity testing should be considered to fully determine whether the soils should be classified as Hazardous.

Direct toxicity testing
The Environment Agency state (Ref 18) that if a 100mg/l WAF leachate (equivalent to a 0.1g/l leachate) produces a toxic effect of >50%, the sample should be classified as Hazardous on the basis of ecotoxic risk. Therefore, if there is a toxic effect of <50%, the sample should not be classified as Hazardous.

Case study
Chemical analysis was carried out on soil samples from a particular site. Concentrations of up to 15000 ppm lead and 2200ppm zinc were recorded indicating initial classification as Hazardous Waste under H14. Leachability data showed a limited number of samples (approx. 5%) exceeded the EQS for lead. Results for the ecotoxicity testing where both daphnia and algae were exposed to leachates from these soil samples indicated the number of daphnia that died as a result of exposure to the leachate was low (<10%) and the amount of growth inhibition for algae was below the laboratory limits of detection (<10 %). On this basis, it may be argued that in accordance with the EA Guidance, despite the high total concentrations of lead, these soils should not be classified as Hazardous on the basis of ecotoxic risk.

Note: It is understood that the Environment Agency are re-drafting WM2 for H14 which may negate the requirement for speciation and may require WAF only where material is soluble.

A7.3.5 Off-site disposal

Both Inert and Hazardous Waste landfill sites are regulated under PPC permits (or Environmental Permits). Non-Hazardous Waste landfills may be managed under the ‘traditional’ waste management licenses or PPC permits. Waste destined for both Inert and Non-Hazardous Waste landfills must meet specific waste acceptance criteria (WAC) before it can be disposed of. Non-Hazardous Waste landfill sites do not have generic WAC, instead each landfill site retains site specific assessment criteria against which the chemical dataset is screened. This can have implications for the disposal route as is discussed below.

Non-Hazardous – soil disposal
Soils classified as Non-Hazardous may also be considered acceptable at Inert landfill sites, after treatment and provided they comply with the Inert WAC.

Hazardous – soil disposal
Soils that are initially classified as Hazardous (using WM2) may be landfilled at a Non-Hazardous landfill site, after treatment and provided the soils meet the site specific Non-Hazardous landfill WAC. It is recommended that either remediation or earthworks contractors are contacted to discuss treatment options and the potential for such soils to be accepted for Non-Hazardous landfill disposal.

A7.4 Guidance for remediation and waste management

A7.4.1 Treatment or containment

The Environment Agency currently regard soils requiring treatment or containment to mitigate risks to controlled waters as “waste” in accordance with Government guidance (Ref 8 and Ref 22). Accordingly, if the materials are defined as waste, then treatment or containment requires an Environmental Permit (previously waste management licence).

Early discussions with the local Environment Agency waste officer are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for treatment or containment of contaminated soils on-site. Further guidance regarding the re-use of contaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.2 Mobile Treatment Licences

The treatment of contaminated soils or groundwater is a licensable activity (Ref 8) with further useful guidance also provided in Ref 23. Where the type of plant used involves mobile plant, a Mobile Treatment Licence (MTL) is used to regulate this activity. Most remediation contractors will retain a MTL for their specific treatment technology. MTLs require a Deployment Form to be in place. This Form is normally prepared by the Contractor and interprets the MTL in terms specific to the site and the planned treatment activity. Most remediation activities can then be governed by these two documents. There are a number of exceptions to this as follows:

a) Where the remediation is carried out using fixed plant, the waste is Hazardous and the plant has a capacity of more than 10 tonnes per day, regulation is by means of an Environmental Permit (previously PPC permit);
b) Where the remediation is carried out using fixed plant and the waste is Non-Hazardous, regulation is by means of an Environmental permit (previously waste management site licence);
c) Where the remediation is carried out using fixed plant, the waste is Non-Hazardous, is being treated by biological or physico-chemical methods prior to disposal and the plant has a capacity of more than 50 tonnes per day, regulation is by means of an Environmental Permit (previously PPC permit).

A7.4.3 Segregation and sorting

Appropriate levels of site investigation to characterise and delineate contamination on-site should be undertaken to reduce the need for movement and/or recovery or disposal of contaminated materials. Segregation of excavated material doesn't fall within scope of a MTL unless it forms an integral part of it and may require separate authorisation.

A7.4.4 Re-deposition

Currently the Environment Agency position is that if the treated soils are waste, deposition will not be allowed without an Environmental Permit (previously waste management licence). Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of contaminated soils on-site. Further guidance regarding the re-use of contaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.5 Re-use of material brought onto site (Hub and Cluster/Fixed soil treatment facilities)

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of material brought on to site. Further guidance regarding the re-use of soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.6 Sustainability

The principles of sustainability of the various treatment/disposal options should be considered at an early stage when discussing disposal routes etc. for contaminated soils. To assess the sustainability of any of these options a typical set of qualitative parameters by which the sustainability of various treatment/disposal options might be assessed could include; noise, dust, cost, carbon dioxide emissions, requirements for importation of clean backfill and stress on existing road network (especially if in centre of city). An assessment of these factors should use both qualitative and quantitative data and should help inform decisions regarding the most suitable treatment/disposal option.

A7.4.7 Solidification/stabilisation

Stabilisation is often used to immobilise metal contaminants by adding cement to raise the pH and lock the metals into the treated matrix. Metal contaminant concentrations are not reduced through this process and therefore the treated by-product will often remain classified as Hazardous Waste. Currently this makes the re-use of the treated product on-site only possible if an Environmental Permit (previously waste management licence) is in place.

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where solidification/stabilisation is proposed to discuss the potential and requirements for re-use of such soils on-site. Further guidance regarding the re-use of such stabilised soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.8 Asbestos contaminated soils

Many derelict contaminated sites often have fragments of cement bound asbestos roofing (etc.). Soils containing asbestos are generally automatically considered a Hazardous Waste. The following extract from the Technical Guidance (Ref 18) provides advice on the classification of soils containing asbestos fragments.

Examples B17.2

Asbestos
All forms of asbestos, regardless of the chemical form (e.g. chyrsotile, amosite) or physical form (e.g. cement, fibres, dust) are listed as Carc Cat 1: R45 and T: R48/23 in the ASL. All forms of asbestos are regarded as Hazardous Waste, where the asbestos content is greater than the threshold concentration for Carc Cat 1 of >0.1% w/w.

Waste asbestos cement
The Hazardous Waste Directive [Ref 3] relates to hazard and not to risk, the ability of the waste to release free fibres is not relevant for consideration. Waste asbestos cement sheeting typically contains 10-15% asbestos (predominantly chrysotile). Since the limiting concentration for Carc Cat 1 is 0.1% and the waste contains 10-15% asbestos, the waste is therefore Hazardous by carcinogenic (H7).

If asbestos cement sheeting is present in the waste and is separable, the asbestos cement sheeting would be a separate waste to the soil and should be segregated and assessed separately as Hazardous Waste.

The following process should be undertaken where soils containing asbestos have been identified:

1. Estimate how much asbestos cement is present within the soil mass as a percentage.
2. Estimate the total volume of the soil mass.
3. Asbestos identification to positively identify the material and its form.
   In the past quantitative analysis of the cement asbestos has been undertaken to determine the percentage of actual asbestos fibres within the cement bound material. This type of analysis is no longer undertaken by most laboratories. Therefore, recent practice has been to estimate the typical content of asbestos type (Ref 24). An extract of Table 1 showing information regarding cement bound asbestos roof cladding is presented overleaf.
4. Using this data, the proportion of asbestos present in asbestos cement should be multiplied by the percentage estimate on the volume of asbestos cement in the soil/stockpile etc.
5. If this value is less than 0.1% of the total soil volume, the soil should not be classified as Hazardous.
6. Should the stockpile be classified as Non-Hazardous Waste due to asbestos concentrations being less than 0.1% it is recommended that any larger fragments of asbestos cement are removed and disposed of separately. This will ensure that the threshold of 0.1% asbestos by volume for the whole material is not breached.

Extract from HSE MDHS 100. Table 1. Asbestos containing materials in buildings Cement Products

Asbestos product	Location/use	Asbestos content and type/date last used	Ease of fibre release and product name
Profiled sheets.	Roofing wall cladding. Permanent shuttering cooling tower elements.	10-15% asbestos (some flexible sheets contain a proportion of cellulose); Crocidolite (1950-1969) and amosite (1945-1960) have been used in the manufacture of asbestos cement, although chrysotile (used until November 1999) is by far the moist common type found.	Likely to release increasing levels of fibres if abraded, hand sawn or worked on with power tools. Exposed surfaces and acid conditions will remove cement matrix and concentrate unbound fibres on surface and sheet laps. Cleaning asbestos containing roofs may also release fibres. Asbestos cement, Trafford tile, 'Bigsix'; 'Doublesix; 'Super six'; 'Twin twelve'; 'Combined sheet'; 'Glen six'; '3" and 6" corrugated'; 'Fort'; 'Monad'; 'Troughsec'; 'Major tile and Canada tile'; 'Panel sheet'; 'Cavity decking'.
Semi-compressed flat sheets and partition board.	Partitioning in farm buildings and infill panels for housing, shuttering in industrial buildings, decorative panels for facings, bath panels, soffits, linings to walls and cleanings, portable buildings. Propagation beds in horticulture, domestic structural uses, fire surrounds, composite panels for fire protection, weather boarding.	As for profiled sheets. Also 10-25% chrysotile and some amosite for asbestos used for fire doors etc. Composite panels contained approx 4% chrysotile or crocidolite.	Release as for profiled sheets. Flat building sheets, partition board, 'Poilite'.
Fully compressed flat sheet used for tiles, slates, board.	As above and where stronger materials are required and as cladding, decking and roof slates (e.g. roller skating rinks, laboratory worktops).	As for profiled sheets.	Release as for profiled sheets. Asbestos containing roofing slate (e.g. 'Eternit'; 'Turners'; 'Speakers'). 'Everite'; 'Turnall'; 'Diamond AC'; 'JM slate'; 'Glasal AC'; 'Emalie"; 'Eflex'; 'Colourglaze'; 'Thrutone'; 'Weatherall'.
Pre-formed moulded products and extruded products.	Cable troughs and conduits. Cisterns and tanks. Drains and sewer pressure pipes. Fencing. Flue pipes. Rainwater goods. Roofing components (fascias, soffits etc.). Ventilators and ducts. Weather boarding. Windowsills and boxes, bath panels, draining boards, extraction hoods, copings, promenade tiles etc.	As for profiled sheets.	Release as for profiled sheets. 'Everite'; 'Turnall'; 'Promenade tiles'.

A7.5 References

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Annex 8
Summary of remediation technologies
[Reproduced from R&D66: 2000]

Note: The following text has been reproduced verbatim from R&D66: 2000 with the exception of the cost information which is not included here. This is because this cost data is dated and may not be useful or relevant in today's market. More recent information is available about some techniques as referenced in the main text.

A8.1 Summary of methods available for remedial treatment of contaminated land for housing development

A8.1.1 Non-technical options

Of the non-technical options, the mostly common is to change the site layout. During the review and analysis steps of selecting a remedial strategy it may be appropriate to review the zoning or layout of the development to establish whether less sensitive components of development could be placed in the areas of greatest risk from contamination. For example, where high levels of contaminants are found in areas designated for sensitive uses, but low levels are found in areas designated for hardstanding, it may be possible to revise the layout to ensure that the sensitive uses are relocated to areas of low contamination so that assessment criteria for those uses would not be exceeded. Similarly, if criteria are exceeded for private gardens, the form of development could be changed to replace private gardens with communal gardens, thus removing the risk of exposure to contaminated home-grown produce.

This approach may save on the costs of remedial treatment. It can often prove more sustainable than removal or treatment of contamination to allow the original form of development because it minimises the amount of disturbance and reduces reliance on limited environmental resources such as landfill for the treatment or disposal of the contamination.

Where changing the site layout is not possible, or changes cannot achieve the risk management objectives, consideration may be given to restricting certain activities on the site after completion of the development in order to protect residents and other sensitive receivers. Controls on construction of outbuildings such as sheds and greenhouses may be effective where there is a risk of accumulation of methane and other gases from the ground. Prohibition of excavation for swimming pools or other below-ground structures might be employed to prevent exposure to contaminants at depth in the soil. Such controls might also be necessary where the integrity of a cover system might be breached by excavation. Sometimes, a highly coloured layer is built in to cover systems to warn against breaching them should they be uncovered by excavation.

If changing the form of development cannot mitigate the risks adequately, and the costs of undertaking remedial measures to make the site suitable for housing development are unacceptably high, consideration might be given to developing the entire site for a less sensitive end-use that might not require the same level of remedial treatment. Clearly, this could have planning implications that should be discussed with the local planning authority.

A8.1.2 Technical options

Of the technical solutions, the civil engineering approaches have been the most widely used in past in relation to housing development. In the future it is likely that other methods will find wider applicability. In appropriate circumstances any of them could be applicable to housing developments. Each of the broad categories of remedial technology is briefly described below.

Civil engineering approaches
The Model Procedures identify two principal civil engineering approaches, containment systems and excavation with disposal. The objective of the containment approach is to modify or remove

the potential migration pathways to potential receptors. Containment may be achieved by the use of cover systems and/or barriers.

Cover systems involve the placing of one or more engineered layers of uncontaminated materials over contaminated ground. They may be used to achieve some or all of the following objectives:

- the prevention of contact by acting as a barrier between site users and contaminants;
- the prevention of upward and downward migration of contaminants;
- the ability to sustain vegetation; and
- the improvement of geotechnical properties.

Cover systems are useful where contaminated levels are only marginally above site-specific assessment criteria. In such circumstances, a limited cover thickness of 0.5m is usually sufficient to prevent most, but not necessarily all, contact. If prevention of all contact is required, 1m of cover may be provided. Often, this will incorporate a physical break layer (for example a geotextile) to prevent inadvertent contact with the underlying soils. The design of cover systems must ensure that the protective functions are not impaired when services are installed and repaired. Further details on the design of cover systems is given in the CIRIA report on barriers, liners and cover systems for the containment and control of land contamination. Cover systems are not effective against contaminants that can move laterally through the ground. Such systems are not usually adequate protection in situations where gases are present in the ground or groundwater moves laterally through contaminated material.

In-ground barriers are generally used to prevent the lateral migration of contaminants. Barriers can be created using cement-bentonite slurry trenches or geomembranes. Sometimes, sheet piles are used. They may be used to achieve some or all of the following objectives:

- to isolate contaminants from the surrounding lateral environment;
- to modify local groundwater flow;
- to reduce contact between groundwater and contamination sources.

In-ground barriers are often used in conjunction with cover systems to isolate contaminants from potential receptors. Barriers may not be appropriate in circumstances where they could block natural groundwater flows.

The dwelling structure, consisting of foundations, sub-structure and ground floor, can provide an effective barrier to certain contaminants. The Building Regulations Approved Document C39 lists metals, metal compounds and mineral fibres found in the ground which will lie within building footprint as not requiring any action (in relation to human health) because the building itself is adequate protection.

If suitably designed and installed, in-ground barriers containment methods can be used to isolate organic and inorganic contaminants in soil, groundwater and also to control the migration of gases. In-ground barriers are used to contain contaminants *in situ*, whilst cover systems can be used in both *in situ* and *ex situ* applications, although they cannot prevent lateral migration in either case. The fundamental limitation of barriers and cover systems is that they leave the contamination in place, so maintenance and monitoring are generally necessary to ensure that they remain effective.

Excavation and disposal of contaminated soil and other materials is currently the most commonly used remedial option. Disposal must be to a suitably licensed waste management site, or a site with an appropriate registered exemption from licensing. The Environment Agency has issued guidance on classification of contaminated soil for the purposes of disposal at licensed facilities.25 Where waste is taken off-site, developers and builders should comply with their obligations under the Duty of Care provisions of the Environmental Protection Act3 which require them to accept responsibility for waste. Waste material sent for disposal should only be carried by registered carriers. If it is proposed that excavated material is to be replaced on-site, it may be necessary to obtain a waste management licence, or a registered exemption from licensing. Advice should be sought from the relevant environment agency in relation to this issue.

Following excavation, it may be appropriate to restore site levels by importing of suitable fill. In such circumstances, it may only be necessary to remove contaminated materials to a depth sufficient to accommodate a cover containment system within the planned site levels. In these circumstances it may be appropriate to leave contaminants on-site below the cover layers, provided that there is not an unacceptable risk to human health or the environment. Where contaminants remain within or beneath cover or containment systems there may be a potential risk to the water environment through their leaching into groundwater.

All imported fill should be thoroughly characterised to ensure that no materials are used that may pose unacceptable risks to potential receptors. Consideration should be given to whether the imported material could be classified as a controlled waste and hence subject to waste management licensing legislation. It is generally advisable to consult the appropriate regulatory authorities to establish acceptance criteria for imported material.

Excavation and disposal may be expensive, particularly in areas with a shortage of suitably licensed landfill sites. In addition, there may be practical considerations that limit its applicability. For example contaminants may be located at depths beyond the practical reach of excavation, or beneath unmovable structures.

Development of housing on land contaminated by landfill gas and other soil gases is possible, but generally only in circumstances where passive measures are sufficient to achieve control. Where gas emission rates and concentrations are so high as to require active measures for control, the regulatory authorities may discourage development for housing.

Various guidance is available on civil engineering based methods to control landfill gas and other soil gases, for example the CIRIA Report 149 on protecting development from methane and the BRE Report on construction of new buildings on gas-contaminated land. Guidance on radon in new and existing buildings is given in the BRE report on guidance on protective measures for new dwellings11 and the Department of the Environment householders' guide to radon.

The principal components of passive protection are as follows:

- gas-resistant membrane;
- cavity tray seal to connect damp-proof course to gas-resistant membrane;
- services entries sealed;
- sub floor ventilation;
- cavity ventilation;
- oversite concrete or membrane below sub-floor voids.

Where passive gas control measures are incorporated into housing development it will be necessary to have a high level of confidence in the durability of the controls and in the provision of long-term maintenance.

Clearly, any such measures aimed at providing a low permeability barrier between the source of gas and the interior of the building will be compromised if the occupants are able to breach it, for example by installing pipework or cabling below floor level or constructing cellars or underfloor storage, or bypass it, for example by building an extension.

Biologically based approaches

Biological remedial methods rely on microorganisms to carry out the aerobic or anaerobic treatment of contaminants, either *in situ* and *ex situ*. Some methods are based on providing favourable conditions for microorganisms which are already present in the soil and water, whilst other methods introduce specially cultured microorganisms. The treatment technologies are normally limited to the treatment of organic contaminants, although some techniques are claimed to treat cyanides and alter soil pH values. There are a wide range of biological treatment options available and it is important to confirm that any method being considered is capable of treating the specific contaminants identified at the range of concentrations likely to be present.

Certain *in situ* biological treatment methods may be particularly appropriate for treating organic contaminants in locations that are not easily accessible by other techniques, for example if they are beneath unmovable structures or at depths beyond conventional excavation techniques. However, some of the biological treatment options may be slow relative to other remedial options, particularly if they are temperature dependent.

Chemically based approaches
These methods make use of chemical processes, either *in situ* or *ex situ*, to reduce the risks from contaminants in the soil or groundwater. This may be achieved by chemical reaction, sorption or by stimulating biodegradation. A wide range of chemical treatment options is available and it is important to confirm that any method being considered is capable of treating the specific contaminants identified within the site and at the range of concentrations likely to be present.

In situ soil flushing techniques may be appropriate for dealing with organic and metallic contaminants in locations that are not easily accessible by other techniques, for example if they are beneath unmovable structures or at depths beyond conventional excavation techniques.

Physically based approaches
These methods use physical processes to remove contaminants from soil and/or groundwater. Some of the *in situ* techniques may be particularly appropriate for dealing with contaminants in locations that are not easily accessible by civil engineering techniques, for example if they are beneath unmovable structures or at depths beyond conventional excavation techniques. They may be used to remediate sites which have already been subject to development. The physical methods considered in the Model Procedures4 are briefly discussed below.

Dual phase vacuum extraction and soil vapour extraction are similar *in situ* techniques involving the use of wells and vacuum extraction to remove vapours, or vapours in combination with free-phase liquid contaminants, from the subsurface. The extracted materials are then treated above ground to remove the volatile compounds. The techniques are generally applicable to volatile and semi-volatile liquids in soil and groundwater. They have been successfully used for the remediation of sites contaminated with petroleum hydrocarbons and in some instances may be applied without moving structures or other infrastructure. Hence it may in appropriate circumstances be applied with a minimum of disturbance to sites that have already been developed. Limitations include the smearing of contaminants during dewatering, possible explosion hazards and operation and maintenance costs if long-term treatment is necessary.

Air sparging is an *in situ* technique for the treatment of volatile organic chemicals in groundwater. Air is injected into the contaminated groundwater and volatile liquids are stripped out of both the dissolved and free phase. The contaminated vapours are then collected for further treatment. In some instances the technique may be applied without moving structures or other infrastructure. The effectiveness of air sparging depends upon the local geology and hydrogeology which controls the air flow around the well head. The technique may lead to the wider dispersion of contaminants and the injection of air may cause chemical precipitation, which can affect flows in the aquifer and also encourage the growth of microorganisms. These factors should be considered before adopting this technology.

Soil-washing and physico-chemical washing are closely related *ex situ* techniques that typically combine physical and chemical processes. Soil-washing generally relies on contaminants being concentrated in separable soil fractions, for example contaminants may be bound to the clay fraction whilst the sand fraction may be relatively uncontaminated. If contamination is distributed across all the soil particle sizes, soil-washing is unlikely to be effective. Soil-washing plant are often based on mineral processing technologies and may include the use of many technologies, for example screens, crushers, water sprays, froth flotation tanks, filter presses, water treatment systems etc. During physico-chemical washing the separated soils are treated in a special reactor with a washing liquid, generally an aqueous solution containing chemicals to either dissolve or adsorb the contaminants. The resultant leachate is then separated from the treated solid for further processing. By use of the appropriate combination of technologies, a wide range of organic and inorganic contaminants can be treated.

Solidification and stabilisation
These technologies are used to 'fix' contaminants in soil and thus reduce the risk of harm. The solidification and stabilisation can include mixing the soil with a cementitious material to produce stable solid, or the use of high temperature vitrification processes to produce a glassy product. Both approaches are typically used *ex situ*, although *in situ* techniques have been developed. The presence of organic contaminants may adversely affect cementitious processes, whilst vitrification is applicable to a wider range of contaminants. It is, however highly energy intensive.

Thermal processes
These involve the use of *ex situ* thermal processes to alter either the contaminants in soil, for example by incineration, or by the use of thermal desorption techniques, to volatilise contaminants from the soil so that they can be either treated or burned. Incineration may be used to treat a wide range of organic and inorganic contaminants, but the treated soil is effectively destroyed and the residue subject to the same regulatory control as other incinerator residues. Thermal desorption processes can treat a range of organic and inorganic contaminants, but may have limited applicability in tightly aggregated soils. Careful consideration has to be given to the treatment of the vapours produced during thermal desorption since these may be polluting and can also pose an explosion risk.

A8.2 Technology summaries for remediation of contaminated land

The following technologies for remediation of contaminated land are summarised in this appendix:

- Containment;
- Excavation and disposal;
- *In situ* biological treatment;
- *Ex situ* biological treatment;
- Natural attenuation;
- Physical treatments;
- Chemical treatments;
- Solidification and stabilisation;
- Thermal processes.

A8.2.1 Containment

Introduction
The objective of containment is to modify or remove the potential migration pathways between the source of contamination and its potential receptors (for example on-site users or groundwater). Cover systems are usually installed as a long-term solution (design life times are measured in decades) and must be carefully integrated with the future use of the site. The exact construction of the system depends on the ground conditions and the nature of the contamination present. There are three main types of containment, namely cover systems, in ground barriers and hydraulic barriers. Reactive walls are a variation on the theme of barriers in which the barrier contains a reactive material (for example a chemical reactant or active microorganisms) which can treat contamination that comes into contact with it. There is little experience in the UK with such systems, however, and they are not considered in detail here.

Cover systems
Cover systems involve the placement of one or more layers of uncontaminated, inert materials over contaminated ground. They can be used to address the following problems:

1. the exposure of on-site users to contaminated soil by skin contact with the disturbed soil surface which may result from activities such as gardening;
2. the upwards movement of contaminants in groundwater or non-aqueous phase liquids following flooding or excessive rainfall;
3. the uptake of contaminants by homegrown vegetables;
4. the upward movement of soil moisture by capillary action following a period of drought;
5. the migration of contaminant vapours and gases;
6. the downward infiltration of rainwater into the contaminated ground.

Examples of cover materials include the following:

1. natural granular soils (such as gravels) are used in capillary breaks and for drainage channels;
2. natural fine soils (such as clays) are used as barriers to upwards or downwards water flow;
3. soils modified by cement or bentonite are used to improve geotechnical properties;
4. wastes such as crushed concrete and fly ash are used as cheaper alternatives to natural soils;
5. synthetic membranes such as geotextiles are used to prevent gas and water migration.

In-ground barriers
The principal functions of in-ground barriers are: to isolate the contaminants from the surrounding environment; and to modify local groundwater flow to modify and reduce the contact between groundwater and the contaminated source. They are often used in combination with cover systems and hydraulic containment to isolate a contaminated site completely from its surroundings (that is macro-encapsulation). Hydraulic containment is often required to reduce the risk of infiltrating rainwater raising the site water table as a result of the interruption of natural drainage pattern. The effectiveness of installed barriers depends on the type of contamination and the local geology and hydrogeology. In-ground barriers can be used to contain groundwater, free phase liquids and gases.

The most commonly used barriers in the UK are based on sheet piling or slurry trenches. Steel sheet piling is an example of a displacement technology where the large sheets of steel are driven or vibrated into the ground with minimal ground disturbance. Vibration methods can emplace sheets to a depth of 30m. The joints between sheets are often grouted to ensure that the barrier is impermeable. Steel sheets are generally resistant to site contaminants, particularly organics, but may require specialist anti-corrosion coatings in low pH soils. Steel sheeting is normally used where structural or mechanical support is also required.

Slurry trench walls are formed by excavating a trench filled with a bentonite-cement slurry (called a “self-hardening” slurry). While the trench is excavated this slurry remains fluid exerting hydrostatic pressure in order to prevent the trench walls collapsing (thereby allowing excavation down to over 40m). After excavation the slurry hardens to the consistency of a “stiff clay” and forms an impermeable barrier wall with maximum permeabilities in the order of 10-9 m/s. A synthetic liner such as a geotextile may be introduced during wall construction to decrease permeabilities further and/or to improve chemical resistance of the wall.

Hydraulic containment
The objective of hydraulic containment is to modify and/or remove the potential migration pathways between the source of contamination and its potential receptors. Hydraulic containment uses groundwater abstraction and re-injection to manipulate the subsurface hydrology and thereby control the migration of contaminated groundwater or in some cases non-aqueous phase liquids. It does not necessarily involve treatment of soil or groundwater although hydraulic systems may be combined with above-ground water treatment or can be used to treat contaminated soil as an *in situ* treatment delivery system.

Hydraulic measures for containment can be classified according to three main objectives:

1. to achieve the separation or isolation of the contaminants from the site groundwater by lowering the water table;
2. to contain or isolate a contaminant plume. The migration of contaminants from the original source depends on a number of parameters including contaminant type, the groundwater flow regime, and the hydrogeological ground conditions. The size and shape of a plume is usually defined by the “unacceptable” concentration of contaminants found at its boundary;
3. to manipulate the hydraulic regime to control and direct groundwater flow patterns so that contaminant migration is minimised. For example, hydraulic measures may be used to direct groundwater inward rather than outward from a site or to divert contaminated groundwater flow from a sensitive use discharge point.

Most hydraulic measures are implemented using well and pumping systems installed singly or in groups. Where the water table lies close to the surface, drainage trenches may sometimes be used. Three types of well are commonly used: abstraction wells to pumpout groundwater for controlled discharge or further treatment; injection wells to introduce clean water and treatment reagents; and monitoring wells.

Installation of hydraulic containment measures critically depends on a detailed understanding of local and regional hydrogeology. Therefore a detailed site investigation (both geotechnical and chemical) is an essential prerequisite to installing such a system.

Applications
Containment is generally applicable to a wide range of soil types as well as made ground and sediments. It is also effective for a wide range of contaminants, although under high loading pressures some contaminants such as tars and other non-aqueous phase liquids can be forced through the barrier materials.

Specific technical limitations
The fundamental limitation of containment is that the contamination remains in place. The long-term effectiveness is open to doubt with very little information being available on installed systems. Mechanisms for barrier failure are numerous and include desiccation, cracking of clay layers and inappropriate designs for a specific site.

A8.2.2 Excavation and disposal

Introduction
Excavation and disposal of contaminated soil and other materials are important methods for dealing with contaminated land in the UK. Disposal can take place on or off-site in a suitably licensed repository. The method is versatile and able to deal with a wide range of problems. On-site disposal of contaminated soil is applicable to large sites where the placement of a safe storage facility does not interfere with site use or redevelopment. It allows transport cost savings where a suitable off-site landfill facility is a considerable distance from the site.

Approach
Excavation and disposal usually consist of the following tasks:

1. site preparation. This includes management operations such as implementing site security, emplacing containment measures, obtaining regulatory permits, selecting local haulage routes, and the setting-up of “dirty” and “clean” work areas;
2. excavation operation;
3. materials handling. This stage may include rudimentary measures to ensure segregation of contaminated from un-contaminated materials, dewatering, and/or recycling of materials for re-use (e.g. crushing of site debris);
4. post-treatment validation. Investigation and monitoring to ensure that remedial objectives have been met;
5. off- or on-site disposal. This stage involves identification of an appropriate licensed facility for disposal of the contaminated materials;
6. materials replacement. Where excavation and disposal is associated with site redevelopment it may be necessary to import new material to replace that removed.

Planning of excavation and disposal operations should ensure that the appropriate regulatory permits are obtained. These may include a waste management licence (for on-site disposal), discharge consents for liquid effluents, permission to abstract groundwater, development of site specific health and safety plan, and approvals regarding sensitive receptors (for example protected species).

Applications
Excavation can be effective for all types of ground and all types of contaminant, but is not applicable to contaminated groundwater.

Specific technical limitations
Although excavation and disposal may offer the potential for a “complete” solution to contamination at a particular site this is not always the case. In practice, the complete removal of contaminated material is not possible: contaminants may be located at depths beyond the practical reach of excavation plant or beneath unmovable structures such as buildings or

services. Under the “Duty of Care” regulations in the Environmental Protection Act (1990) the owner/producer of contaminated materials and those who handle it have a legal responsibility to ensure its lawful and safe disposal.

A8.2.3 *In situ* biological treatment

Introduction

There are two main types of *in situ* biological treatment, namely bioventing and bioremediation using groundwater recirculation. Bioventing is an approach for optimising biodegradation in soil through the *in situ* supply of oxygen to indigenous microbial populations. Bioventing systems are the product of process integration, combining features of *in situ* soil vapour extraction with bioremediation. Bioremediation using groundwater recirculation seeks to simulate *in situ* biodegradation of contaminants by the addition of dissolved oxygen (or another oxidant such as hydrogen peroxide) and nutrients to groundwater, which is recirculated through the soil in order to optimise treatment conditions. Treatment may be attempted using indigenous microbial populations or laboratory-prepared inocula. Other chemical additives, such as surfactants, may be added to reduce contaminant toxicity to micro-organisms or to increase contaminant bioavailability.

Bioventing

In bioventing systems, oxygen is supplied to the soil using a combination of the following:

1. injection of air into the contaminated zone with a vacuum extraction gradient towards wells positioned outside the contaminated zone;
2. injection of air into the subsurface outside the contaminated zone with a vacuum extraction gradient towards wells positioned inside the contaminated zone;
3. vacuum extraction of air by wells positioned inside or outside the contaminated zone.

Dissolved nutrients and water may be supplied either by percolation from the surface or via a small network of vertical wells and horizontal galleries. Bioventing occurs in the vadose zone and treatment can be extended by artificially lowering the water table. It has been reported that bioventing has been applied to a depth of over 30m.

Bioventing systems are designed to maximise aerobic degradation. Operating flow rates of air are low to minimise volatilisation, and the potential need for treatment of extracted air may, therefore, be lower than for soil vapour extraction systems. The optimum balance between biodegradation and volatilisation depends on contaminant type, site conditions and the time available for treatment. However, facilities for treating extracted air are often still required. This usually includes an air/water separator and an air treatment system such as activated carbon, biofilters, or catalytic oxidation.

In situ biotreatment using groundwater recirculation

In situ biotreatment systems aim to supply oxygen to the soil in aqueous solution in one of the following ways:

1. abstraction and re-injection of groundwater to achieve circulation through contaminated soil. The groundwater is treated in above-ground effluent treatment plant where nutrients and oxygen (or oxygen “carrying” chemicals such as hydrogen peroxide) are added. This process is commonly known as pump and treat;
2. addition of nutrients and oxygen (or chemicals such as hydrogen peroxide) by slow infiltration into the soil surface via a network of vertical wells and/or horizontal galleries in the contaminated soil zone;
3. using an engineered auger system for mixing shallow layers of contaminated soils and for the injection of aqueous solutions of nutrients and oxygen.

To prevent the further dispersion of contamination and the migration of process chemicals (such as surfactants or inorganic nutrients) during treatment, isolation of the contaminated zone is often achieved using either hydraulic or containment barrier methods.

In situ treatment can also be carried out by tilling and ploughing the contaminated soil in a method similar to landfarming where the contamination is confined to a near surface shallow layer.

Applications
Bioventing can be used to treat sands and silts, as well as made ground, sediments and groundwater. It is effective against a range of organic contaminants. Bioremediation using groundwater recirculation has similar applications, but is less effective in made ground.

Specific technical limitations
Bioventing offers advantages over *in situ* bioremediation using aqueous delivery systems because the concentrations of air achievable in the subsurface can be much higher than in systems relying on water as a carrier. However, the effectiveness of bioventing systems is limited by the moisture content in the vadose zone. A saturated soil zone will require that the water level be reduced before bioventing can be carried out.

Significant questions have been raised over the accessibility and availability of subsurface contaminants to *in situ* systems. Bioventing and nutrient addition, usually as an aqueous solution, are in competition for available soil pore space and, therefore, may be mutually antagonistic.

Limitations of groundwater recirculation derive from the delivery systems used to supply nutrients and oxygen to the biologically active zone. Pump and treat systems are limited by factors such as soil heterogeneity, which makes prediction of contaminant migration difficult on even a macro scale for many sites. A reported rule of thumb is that, for successful applications, subsurface hydraulic permeabilities must be greater than 10-2 m/s. Water is a poor carrier of oxygen and treatment is often limited by lack of oxygen due to this. In using hydrogen peroxide, the oxygen carried increases but the presence of iron and manganese and other catalytic surfaces in the subsurface environment promotes hydrogen peroxide decomposition.

A8.2.4 *Ex situ* biological treatment

Introduction
There are four main types of *ex situ* biological treatment. In biopiles, biological degradation of contaminants is achieved by optimising conditions within a soil bed or heap. The critical element in this process is aeration. 'Landfarming' uses a treatment-bed approach in which biological degradation of contaminants is achieved by optimising conditions within a ploughed and tilled layer. Windrow turning is an *ex situ* biological treatment process using raised treatment beds and waste composting technology. Biological degradation of contaminants is achieved by optimising conditions within a raised soil bank ("windrow") amended with bulking agents to improve structure and aeration. Slurry-phase biotreatment uses a bioreactor for accelerating the biodegradation of soil contaminants. Excavated soil is slurried with water and mixed with degrading organisms, air, and nutrients in one or more reactors. After treatment the slurry is dewatered; the process water may be treated to remove organic and inorganic contaminants and is commonly recycled.

Treatment may often include the use of amendments such as sewage sludge or other organic wastes, such as vegetation, to provide structure, nutrients, and additional microbial degraders.

Biopiles
Treatment using biopiling involves excavating and stockpiling contaminated soil, commonly on an impermeable base. The base is required to prevent uncontrolled runoff of any leachates that form during the bioremediation process. Analysis of the leachates may be used to monitor nutrient or contaminant concentrations, as a mechanism to ensure consistent and favourable conditions are maintained. A network of support piping may be installed to provide a route for introducing nutrients, moisture, and aeration, depending on the level of sophistication required for the engineered heap. The network of piping may be installed at the base of the heap, within the heap, or on the surface of the heap depending on its function, for example at the base for air extraction and on the surface for irrigation. Biopiles have been built as high as 4 m although adequate aeration and possibly process temperature control is more difficult with increasing pile height. Volatile and gaseous emissions can be controlled by collection through use of a heap enclosure (for example portable greenhouses) or more commonly by drawing air through the system. Contaminant emissions can be removed from the drawn air using a biofilter or by adsorption onto activated carbon. Biodegradation is usually carried out using biostimulation of indigenous microbial communities but introduced organisms have also been used.

The rate of biological processes is temperature dependent and seasonal variations may affect the rate of degradation. Temperature can be controlled by enclosing the pile in a greenhouse-type structure or by heating the air/water entering the pile.

Landfarming
Landfarming was first used for the treatment of refinery wastes from the petroleum industry. A range of landfarming methods exists, ranging from simple to complex techniques. It can be carried out on-site or at a fixed off-site facility. Typically excavated contaminated soil is spread over a cleared and prepared area to a thickness of about 0.5m. To protect the underlying soil, a liner is sometimes used to contain leachates which may form during treatment; however, this type of containment means that cultivation must be carried out carefully. In more advanced and engineered systems, a layer of permeable sand may be placed on top of the liner with a network of drainage channels for leachate collection. An additional role of a sand layer is to protect the liner during the laying of the soil treatment bed so that it may be reused several times. Using standard or slightly modified agricultural techniques, the soil layer is ploughed and tilled to improve soil structure and increase aeration. Aeration is achieved by cultivation. The moisture content can be optimised by adding water at periodic intervals and, if necessary, nutrients.

Several types of landfarming processes cover the soil layer with a modified plastic film greenhouse which both prevents escape of volatile emissions and provides protection from the weather.

Windrow turning
Windrow turning is carried out on-site or at a fixed off-site facility. Excavated contaminated soil is heaped on a cleared and prepared area to a height of 1-2 m. Placed underneath the treatment bed a liner may be used to contain the leachates that may form during treatment. Materials such as wood chips, bark or compost are commonly added to improve drainage and porosity within the heaps and, in some cases, these materials can be microbiologically pretreated as proprietary seeding materials. Drainage galleries may be installed to collect and recycle percolating water and maintain an optimum moisture content within the pile.

Windrows may be mixed (or “turned”) using agricultural machinery or specialised compost manufacturing machinery. Turning enhances biodegradation by improving homogeneity, providing fresh surfaces for microbial attack, assisting drainage, and promoting aeration. Otherwise, aeration in the process is passive.

Windrow turning requires significantly more area than *in situ* treatment since the soil is treated above ground, but is likely to require less area than landfarming since bed thickness is considerably greater. Moisture content and temperature are critical process control parameters.

Slurry-phase biotreatment
A generalised example of the process steps of a slurry-phase-based treatment is outlined below:

1. pretreatment of the feedstock to remove rubble, stones, metal objects etc. and produce an optimum particle size range for the slurry process (for example <4mm);
2. mixing of the feedstock with water to create a slurry (typically between 20-50% by weight of soil);
3. mechanical agitation of the slurry in a reactor vessel to keep solids suspended and to optimise contact between contaminants and micro-organisms;
4. addition of inorganic and organic nutrients, oxygen and pH control reagents. Some slurry systems may also use oxidants such as hydrogen peroxide, ozone and UV light as a chemical pretreatment to reduce the primary organic contaminants to more degradable intermediaries;
5. possible addition of microbial organisms either initially to seed the reactor or on a continuous basis to maintain optimal biomass concentration;
6. dewatering of the treated slurry on completion of the treatment, with further treatment of residual aqueous waste streams where appropriate.

Slurry-phase bioremediation can also be carried out on-site in lagoons. In certain cases lagoons may already be present, in which case this treatment could be described as *in situ*. These lagoons often contain hazardous liquid waste in addition to contaminated soil. Lagoon-based systems do not incorporate physical separation as pretreatment. Mixing is carried out using specialist equipment which often includes an aeration and nutrient addition system.

Applications
These methods can be used to treat degradable organics, including PAHs and non-halogenated compounds. They may also be effective for cyanides. They are effective in granular soils, such as sand and silts, but not clays and peats. They can also be used to treat made ground and sediments.

Specific technical limitations
Often biopile processes and landfarming may have a beneficial effect on soil structure and fertility. Windrow turning may also have a beneficial effect, especially if bulking agents are added. However, slurry phase treatments may have a severe adverse effect on soil structure since treatment is often accompanied by some form of physical pretreatment to separate the soil into sized fractions. The use of chemical agents such as hydrogen peroxide may also lead to soil damage, for example through interaction with soil organic matter which either may be destroyed or altered into potentially more toxic forms. It may be possible to overcome these effects during post-treatment where the reconstruction of a fertile soil could be emphasised. Some *ex situ* techniques offer improved process containment over *in situ* approaches, although several USA vendors do not recommend their processes for remediation of VOC-contaminated soils because of concern over atmosphere emissions during treatment. However, the opportunity to use landfarming processes critically depends on the space available since the treatment bed is usually no thicker than 0.5m and, therefore, covers a relatively large area. Where landfarming is used without a liner it has no process containment and contamination of topsoil beneath the treatment bed may occur. In this case the soil base should be monitored for the build-up of heavy metals which may leach out of repeated soil applications.

A8.2.5 Natural attenuation

Introduction
Naturally occurring processes may act to reduce the concentration and environmental load of a pollutant within soil and aquifer systems. Physical, chemical and biological processes may act on a contaminant to restrict its movement; disperse the contaminant so that its concentration decreases; or degrade the contaminant so that the overall contaminant load declines. The most important processes that are generally included within the umbrella of 'natural attenuation' are biodegradation, retardation, sorption, hydrodynamic dispersion, dilution and volatilisation.

Approach
The potential for the successful application of natural attenuation depends principally on the nature of the pollutant and the hydrogeochemical environment in which it is located. It is most applicable for reactive (degradable) pollutants and pollutants subject to significant retardation, particularly when located in low permeability aquifer systems. Pollutants that are persistent and/or bio-accumulative, or located in highly permeable aquifers which allow rapid groundwater and contaminant plume migration, are less likely to be suitable candidates for a natural attenuation remediation.

Before adopting a natural attenuation strategy, it is fundamentally important that comprehensive site investigation and characterisation is undertaken, and that the processes are shown to be active at a rate will ensure protection of all receptors throughout, and following, the remedial period.

Natural attenuation is not a 'do-nothing' approach. Environmental monitoring of the contaminant plume and aquifer conditions during the remedial operation is likely to be significantly more intensive than would be necessary for other remedial technologies. The principal advantages of natural attenuation are low capital costs associated with treatment plants and relatively low disturbance of surface activities, which may continue undisturbed during the treatment period.

Applications
Natural attenuation can be used for groundwater contaminated by some organic contaminants, heavy metals and some inorganic substances.

Specific technical limitations
The application of natural attenuation has been demonstrated for a range of aliphatic and aromatic hydrocarbons (based on biodegradation) and heavy metals (based on retardation). Although there is increasing evidence to suggest that natural attenuation may also be applicable to chlorinated solvents in some situations, however there is concern over the potential for

degradation of the chlorinated solvents to form more toxic breakdown products. Little information is available on the suitability of this treatment method for other contaminants or the complexities of treating contaminant mixtures.

A8.2.6 Physical treatments

Introduction
There are two main types of physical treatment. The first involves washing of the soil. Soil-washing is an *ex situ* physical treatment involving mechanical and chemical separation of contaminants or contaminated soil particles from uncontaminated soil. Soil-washing systems are often closely related to *ex situ* chemical extraction and leaching processes.

The second type of physical treatment involves extracting of substances from soil in the vapour phase from soil or groundwater. This is achieved either by applying a vacuum to suck~the vapour out or by sparging with air to flush it out.

There are three main variants of technologies relying on extraction of contaminants in the vapour phase .Air sparging is an *in situ* approach for the treatment of groundwater contaminated with volatile organic chemicals such as benzene, toluene, ethylbenzene and xylene (BTEX). The principles of air sparging are related to both air stripping (an established waste treatment) and soil vapour extraction (SVE). The process exploits differences between the aqueous solubility and volatility of contaminants to transfer contamination from groundwater to the vapour phase. Soil vapour extraction (SVE) is an *in situ* physical treatment process, which exploits the volatility of certain contaminants to remove them from the soil. A vacuum is applied to wells installed in the ground and the air that emerges is treated to remove the contaminant vapour. Dual-phase vacuum extraction is a variation on SVE in that, in addition to extraction of contaminant vapour in air, any free product (that is a non-aqueous solvent layer floating on top of the groundwater) can also be extracted as a liquid. The liquid and vapour phases may be extracted together or separately.

Soil-washing
Many soil-washing systems and techniques evolved or were adapted from the mineral processing industry, where methods were developed for separating valuable ore minerals from gangue material which does not contain economically extractable minerals. Commercially operated soil-washing systems can be fixed at a central facility or installed on-site. Each configuration of plant design is based on the results of a treatability study that investigates the contaminant distribution within the soil. The principal stages in soil-washing can be identified as follows, although not every step will be used for a site specific treatment scheme:

1. deagglomeration and slurrying of soil using water sprays, jets, and low intensity scrubbers. Surfactants may be added to improve suspension of fine particles;
2. high intensity attrition of soil using high pressure water sprays and centrifugal acceleration or vibration can be used to remove surface coatings of contaminants and fine contaminated particles from larger particles such as sand and gravel;
3. sizing and classification of soil to separate soil particles according to size and settling velocity using screens and hydrocyclones. In many instances the coarse soil fractions such as sand and gravel are often less contaminated than finer silts and clays because of their lower surface area and adsorption capacity;
4. further segregation based on differences in density (using jigs, spirals and shaking tables), surface chemistry (using froth flotation), and magnetic susceptibility (using a magnetic separator) may be used to concentrate contaminants into a smaller soil volume or to produce fractions more amenable to specific further treatment;
5. dewatering of all fractions produced by separation, for example, by filtering or flocculation;
6. process water treatment may be necessary if contamination has been mobilised into solution.

Air sparging
A qualitative assessment of the applicability of air sparging to a specific contaminant can be made from its Henry's Constant which is the ratio of its aqueous solubility to its vapour pressure. The basic air sparging system involves the injection of air into the contaminated groundwater from below the water table. As the air bubbles rise to the surface there is a preferential transfer of volatile contaminants from the dissolved or free phase to the vapour phase. The contaminated

vapours are collected at the surface for further treatment by using a series of injection and extraction wells to control subsurface airflow. Above-ground treatments of the collected vapour may include activated carbon filters, biofilters, and condensers.

Soil vapour extraction (SVE)
In the basic SVE design, vertical or horizontal wells are sunk into the contaminated soil. Horizontal wells are used for shallow contamination problems (less than 3m) or where a high water table restricts the depth of vertical wells. A vacuum is applied to a number of these wells to draw air slowly through the contaminated soil, where it is treated above ground by a combination of an air/water separator and an off-gas treatment system such as activated carbon. Although the general direction of airflow can be controlled, for example by placing the extraction wells either inside or outside the contaminated zone, air drawn through the soil will follow the pathway of least resistance. Air drawn through the soil pores carries volatile vapours away by a process known as advection. Contaminants continually vaporise from one or more of the condensed phases (dissolved, free, adsorbed) to maintain equilibrium within the pore space. In soils of lower permeability, the volatile contaminants diffuse to the preferential airflow pathways where advection draws them to the surface.

A8.2.7 Dual-phase vacuum extraction

Dual-phase vacuum extraction is complementary to soil vapour extraction (SVE) and involves the following processes:

1. dewatering of saturated soils to allow enhanced use of SVE technology;
2. recovery of non-aqueous phase liquids (NAPL) and dissolved contaminants. Dewatering is typically carried out in the smear zone at petroleum hydrocarbon release sites where the light non-aqueous phase liquid (LNAPL) contamination can be present as immiscible product or as residual saturation within the capillary zone;
3. control of the upwelling effects caused by application of a vacuum to the soil;
4. increasing groundwater recovery rates.

Free-product removal is an important consideration in a site remediation scheme since (i) it contains a significant proportion of the contaminant mass, (ii) it provides a long-term source and (iii) removal of free-phase can improve groundwater quality considerably. It is imperative therefore that the design of a dual-phase extraction system should be such that the selected ground water clean-up criteria or objectives can be achieved.

Applications
Soil-washing can be used to remove a wide range of organic and inorganic contaminants and heavy metals from many soil types (excluding clay). The other techniques are effective for a range of volatile and semi-volatile organic contaminants in soil and groundwater.

Specific technical limitations
Soil-washing systems depend on a readily exploitable contaminant distribution within the soil to affect remediation. If contamination is widely distributed across soil particles according to size and composition then soil-washing is unlikely to be effective. Economically, soil-washing systems are best applied to treat soils with a silt and clay content below 30-40 percent by weight, since these often represent the most contaminated soil fractions and would therefore incur higher disposal costs. Fine particle sizes also present a materials handling problem. Soil-washing can have a severe effect on soil structure and fertility since it is subjected to slurrying, mechanical abrasion and exposure to toxic process chemicals.

The effectiveness of air sparging, dual-phase vacuum extraction and SVE depends on the subsurface geology and hydrogeology which controls both the groundwater and air flow around the well head. Low permeability soils reduce the accessibility of SVE to reach all contamination. At complex sites the heterogeneous nature of the subsurface can make process monitoring and verification of treatment performance difficult.

Air emissions produced at the surface may require above-ground treatment at additional cost, for example by catalytic oxidation. Where vapour concentrations are very high an explosion hazard may exist.

A8.2.8 Chemical treatments

Introduction
A fairly diverse range of chemical treatments is available for contaminated soil. Some are closely related to physical treatments and could be classified as either. Five chemical treatments are considered here. Two of these, namely surface amendment and soil flushing, are *in situ* technologies. Surface amendment covers a range of *in situ* chemical treatments that have been developed for the remediation of surface or shallow depth contamination. They involve adding of process chemicals directly to the soil and are designed to transform and immobilise (and hence stabilise to some degree) a range of organic and inorganic contaminants. Soil flushing is an *in situ* chemical treatment process where soil contaminants are transferred to an aqueous leachant which is recovered from the subsurface and treated by conventional effluent treatment processes.

Three *ex situ* technologies are also considered. These are chemical dehalogenation, solvent extraction and physico-chemical washing. Chemical dehalogenation involves a chemical reaction in which chlorine or fluorine atoms are split off from halogenated molecules. The dehalogenated compounds produced are generally less toxic or harmful than the halogenated species. Solvent extraction is an *ex situ* treatment which involves the transfer of soil contaminants into either an organic or a supercritical fluid (SCF)-based solvent. This solvent is separated from the soil for further processing and/or disposal. Physico-chemical washing is an *ex situ* treatment which typically combines physical and chemical processes and so could be included in either category. It is often considered as simply an enhancement of soil-washing systems. Treatment involves the mobilisation of soil contaminants into a liquid (usually an aqueous solution) which is then separated from the treated solid for further processing.

Surface amendment
Lime addition involves applying of lime to the soil as a powder or in aqueous solution. The lime may be ploughed into the soil surface using conventional agricultural techniques. Liming the soil raises the pH, thereby reducing the bioavailability of many heavy metals through increased soil adsorption.

Organic matter may be added to the soil as manure or sewage sludge to reduce bio-availability of heavy metal contaminants. The material is ploughed into the soil surface using conventional agricultural techniques. Many heavy metals are strongly adsorbed by organic matter and are thereby more firmly held within the soil.

Chemical reduction uses reducing agents such as sodium polythiocarbonate and ferrous sulphate added to contaminated soils as powder or aqueous solution to treat metal contaminants such as chromium. Cr(VI) is a highly toxic and mobile element which can be reduced to an immobile form Cr(III). Organic matter is an important amendment in the reducing process and acidic conditions are also required (pH 4.5-5.5). After treatment, liming raises the pH and precipitates Cr(III) hydroxide.

Soil flushing
Soil flushing can be executed by two mechanisms, depending on depth of contamination. For shallow depths the flushing solution is delivered by infiltration from the soil surface, where it percolates slowly downwards through the contaminated soil. Leachate which has passed through the contaminated area is collected along ditches or horizontal galleries where it is pumped to a surface treatment plant.

For contamination at greater depth, for example within aquifer sediments, a pump and treat system may be used. The flushing solution is injected and abstracted through wells in the contaminated zone. Contaminated solution is pumped back to the surface for surface effluent treatment. The aqueous-based leachants used in soil flushing are generally either inherently more environmentally benign or used at far lower concentrations than for the corresponding *ex situ* methods. After treatment is complete the majority of reagent is recovered above ground for further processing. Typical reagents include the following:

1. acids for heavy metals and "basic" organics such as amines and ethers;
2. alkalis for some metals such as tin and lead, and some phenols;
3. complexing agents for metals;
4. surfactants for non-aqueous contaminants such as mineral oils.

After treatment it may be necessary to return subsurface conditions to environmentally acceptable limits, for example, by adding alkalis to neutralise any excess acid still present.

Chemical dehalogenation
The two variants of chemical dehalogenation are as follows:

1. chemical system which uses specific proprietary agents to achieve dehalogenation in a reactor system operating at temperatures up to 180°C;
2. thermal and chemical system which uses elevated temperatures (above 850°C) and reducing conditions to achieve thermal reduction of halogenated contaminants.

An example of a chemical system is the APEG process which uses an alkoxide compound to react with chlorinated hydrocarbon contaminants to form a glycol ether and an alkali metal salt. The alkoxide is commonly formed by reacting an alkali metal hydroxide (usually potassium) with an alcohol or glycol, such as PEG 400. Dechlorination may proceed to completion, although replacement of a single chlorine is sufficient to make the reaction products water soluble. The basic treatment process can be divided into several stages: soil preparation; soil and reagent mixing; soil and reagent separation; and soil post-treatment.

Soil preparation includes screening in order to remove coarse debris which can damage the reactor. The soil and reagents are combined in a chemical reactor to optimise reagent-contaminant contact. Typical conditions include heating the soil slurry to between 100-180°C and mixing for up to five hours per batch. After the reaction is complete excess reagent is separated from the soil, which is then further treated in order to neutralise the effect of any entrained chemical, for example by the addition of acid.

Thermal dehalogenation processes operate at temperatures greater than 850°C and involve gas-phase reduction of halogenated compounds in a hydrogen atmosphere. Chlorinated hydrocarbons, such as PCBs and dioxins, are reduced to methane and hydrogen chloride in the combustion chamber. Soil and sediment are usually pretreated in a thermal desorption unit to volatilise contaminants which are carried into the reduction chamber by a stream of recirculated gas.

Solvent extraction
Solvent extraction differs from physico-chemical washing since a non-aqueous solvent is used. A typical process consists of three distinct stages: physical pretreatment of the soil; extraction with solvent; and separation and recovery of the solvent.

Soil preparation may include excavation and screening to remove coarse debris. Depending upon the specific process the soil may be slurried with the solvent prior to extraction. In the chemical extractor the soil and solvent are mixed to optimise intimate contact. The reported effectiveness of this technology depends not on the chemical equilibrium between the solvent and the soil but on the rate of transfer of contaminants from the soil surfaces into solution. The extracted organics are removed from the extractor vessel with the solvent and are passed to a separator, where the pressure or temperature is changed, thereby causing the organic contaminants to separate from the solvent. The solvent is recycled to the extractor and the concentrated contaminants are collected for further treatment, recycling, or disposal. The cleaned soil is filtered and dried for reuse or disposal. Vapours produced from the drying stage may be condensed and recycled or treated by effluent control.

In SCF-based systems, liquefied gases such as propane, butane, and carbon dioxide are used as solvents for separating organic contaminants from soils and sediments. In these systems the temperature and pressure of the solvent is maintained close to its critical point where the gas behaves as a liquid. However, the solvent's viscosity and diffusivity are intermediate between a liquid and gas, thereby enabling it to mix intimately with the contaminated soil. Overall, treatment schemes are similar to those for solvent extraction except that the temperature and pressure in the mixing vessel are elevated.

Physico-chemical washing
In physico-chemical washing, excavated soil is slurried with water, classified and separated into different soil fractions by a soil-washing plant. Where integrated with a chemical leaching stage,

separated soil fractions are usually treated in a special chemical vessel or reactor. This is distinct from the use of small quantities of process chemicals, such as surfactants and pH modifiers, which may be used in a soil-washing plant without chemical leaching.

Leachants which are used in commercial systems include: acids and alkalis; surfactants; and chelating agents. Systems developed in the UK include the following:

1. combination of oxidising agent, pH moderator, and chelating agent is used to enhance contaminant solubility;
2. fine-grained particles of exchange resin are mixed into the soil slurry to adsorb contaminants. Resin and soil are separated physically (by size or density) after treatment.

Leaching may be carried out using a series or cascade of stirred chemical reactors which can be either counter-current (flow of leachant opposes slurried flow) or co-current (flow of leachant and slurried soil in same direction). The flow rate is carefully controlled to optimise the residence time for soil and leachant contact. After contact, treated soil and leachate are separated by processes including filtration. Leachate is treated by an effluent treatment system and, where possible, recycled. Treated soil is dried and ready for further use or safe disposal.

Applications
The *in situ* technologies are effective for sandy, silty and peaty soils and sediments. Surface amendment can be effective in changing the chemistry of inorganic substances, while soil flushing is applicable to organic contaminants.

Of the *ex situ* techniques, dehalogenation can treat a range of halogenated substances, including dioxins. Solvent extraction can be used to remove organic substances, while physico-chemical washing will also remove inorganic substances. Like the *in situ* techniques, adequate penetration and mixing of the reactant or solvent with the soil is necessary. Some types of material, such as made ground, may not be easily treatable.

Specific technical limitations
Chemical treatments are generally costly and require considerable energy and chemical reagent inputs. *In situ* systems require a thorough understanding of ground conditions and moderate to high soil permeability.

Some chemicals are reactive with or do not mix with water and other soil components. Where this is an issue, the soil may need to be dried first, thereby adding to the cost of treatment. Some treatments also prevent the reuse of the treated material as soil, because they damage its structure.

With simple amendments the contaminants are not removed from the soil and, therefore, remediation assessed against guideline values expressed as total soil concentration of contaminants will show no effect. The use of soil amendments is a temporary effect and will require repeated applications to ensure that pH and soil organic matter content stay within appropriate limits.

A8.2.9 Solidification and stabilisation

Introduction
Two systems are considered here. The first involves cement and pozzolan-based systems. The selection of suitable binding agents for a specific mixture of contaminants and soil type is applied following a laboratory study. In general, this involves mixing a sample of the soil with a large number of different binders and binder ratios and investigating which mixes perform best in physical tests, such as compressive strength or hydraulic permeability, and chemical tests, such as leachability. Binder additives include Portland cement, fly ash, soluble silicates, organophilic clays, and lime.

The second system involves vitrification. This is typically used *ex situ*, although it has also been demonstrated as an *in situ* approach. It may also be considered as a thermal treatment. Vitrification involves the application of heat to melt contaminated soils to form a glassy product. The high temperatures associated with vitrification result in the combustion of organic contaminants whilst inorganic contaminants, such as heavy metals, are immobilised within the glassy matrix.

Cement and pozzolan-based systems

In situ cement and pozzolan-based approaches involve the use of soil mixing equipment. An example of a soil mixing system which has been developed in the USA and Japan comprises one set of cutting blades and two sets of mixing blades attached to a vertical auger. The auger is lowered into the soil where the rotating blades cut and mix the soil around them. Solidification and stabilisation agents and water can be injected into the mixing zone. Vertical columns of solidified soil are produced as the blade advances into the ground to the maximum depth, and are remixed as the equipment is withdrawn. By carefully controlling where each column is emplaced, the area of contaminated soil can be covered by a network of overlapping columns.

Ex situ treatment can be applied in several ways. The first option is plant processing, in which contaminated soil is excavated and mixed with solidifying and stabilising agents in a specifically designed plant or in plant adapted from other applications such as concrete mixing. A second approach is direct mixing, in which excavated material is transported to a dedicated area of the site where it is spread out in layers and the solidifying agents added using mechanical equipment.

Direct addition and mixing may also be used to treat contaminated sludges and sediments present in lagoon areas and ponds. A third approach is in-drum processing which involves excavation of contaminated soil into drums or other types of container. Solidification and stabilising agents can be added directly to the drums which are mixed using specialist equipment and allowed to set.

Vitrification

An *ex situ* vitrification system consists of a melter, heat recovery system, air emissions control system, and a storage and handling area for feedstock. Many of the commercially available systems are modified from the manufacture of glass. Heat can be delivered by using plasma arcs, hot gases or carbon electrodes.

A UK vitrification system uses a “hot-top” glass-making furnace operating at temperatures of up to 1,500°C for a period of approximately 10 hours. The feed material consists of contaminated soil (up to 50 percent by weight) and glass-making additives such as lime, alumina, sand and cullet (recycled waste glass). The molten glass is discharged from the furnace along a conveyor belt where it undergoes rapid cooling. Off-gases produced during vitrification are cooled from 1,500°C to 770°C by a series of heat exchangers, scrubbed to remove particulates, VOCs, and acid gases, and discharged to the atmosphere.

A US system uses arc plasma heat to detoxify contaminants present in the feed material at temperatures from 1,540°C to 1,650°C. Off-gases from the vitrification chamber are passed to a secondary combustion chamber where they are heated to up to 1,370°C to destroy residual organics.

Applications

These technologies are applicable to a wide range of non-volatile organic and inorganic contaminants and heavy metals in a range of soils and sediments. Cement and pozzolan systems do not work well with peat and made ground, however.

Specific technical limitations

These systems may have difficulty with soils containing either a high level of organics (greater than 5-10 per cent) Low levels of extremely hazardous organics may also be problematic in cement and pozzolan systems. High levels of some substances affect the setting mechanism in each case and must therefore be checked.

A8.2.10 Thermal processes

Introduction

Two technologies are described here. Incineration is an *ex situ* thermal technique which uses high temperatures (800-2,500°C) to destroy contaminants by thermal oxidation. Thermal desorption is an *ex situ* technique which involves two processes: (1) transfer of contaminants from soil to vapour phase via volatilisation; and (2) treatment of off-gases from the first process to either concentrate contaminants, for example by condensation of metal vapours, or destroy them at higher operating temperatures, for example combustion by incineration.

Incineration
A typical incineration system consists of pretreatment, a one or two-step combustion chamber, and post-treatment for solids and gases. The highest temperatures occur within incinerator systems equipped with a secondary combustion chamber for off-gas burning. A key factor in incineration is the length of time the soil remains at the high temperatures within the reactor (the residence time). Depending on the type of combustion chamber used, the maximum particle size which may be treated ranges from 0.3-0.025 m in diameter.

Operating temperatures for transfer of contaminants depend on soil type and the physical properties of the contaminant present. Commonly used temperatures to volatilise organics are in the range up to 600°C and for mercury from 600-800°C.

Thermal desorption
Desorption units can be categorised according to the heating system used, although many commercially available systems use a combination of these methods. Direct heating uses hot air or open flame (for example in a rotary kiln). Indirectly heated systems transfer heat through contact across a metal surface which is usually heated by electricity or a hot fluid such as steam (for example using a rotary screw conveyor).

Post-treatment of off-gases depends on plant-specific factors but may include: combustion at high temperatures (up to 1,400°C) in an after burner followed by gas cleaning and discharge; thermal destruction at moderate temperatures (200-400°C) using catalysts; and conventional gas scrubbers and carbon adsorption.

Applications
Incineration is effective for a wide range of contaminants in all types of soil, including made ground. However, it does not destroy heavy metals and some other inorganic substances, most of which will remain in the ash.

Thermal desorption can be used to remove a range of organics, heavy metals and cyanide from most soils (except peat). In the USA thermal desorption units are often used for small-scale remediation of petroleum spills and may therefore require less space for operation than an incineration unit.

Specific technical limitations
During soil combustion the volatilisation of metals at high temperatures requires expensive off-gas treatment and the generation of alkali metals, chlorides and fluorides can lead to damage to the kiln wall. Careful control of the feed material is required to ensure that system blockages and insufficient heating do not occur. Concern over the use and sustainability of incinerators for hazardous waste treatment have been raised in the UK and the USA.

Incineration systems require considerable energy inputs and are particularly susceptible to fluctuations in cost associated with variable moisture content. Soils treated by incineration are essentially destroyed and must be disposed of according to the waste management regulations applying to treatment residues. At the lower operating temperatures of a desorption unit (100-180°C) the physical structure of the treated soil may be maintained, although organic matter can be oxidised. At higher temperatures the treated residue may no longer resemble a soil at all, but some projects report that soil function may potentially be restored through careful husbandry.

There are several specific operational limitations reported for thermal desorption systems. Tightly aggregated soils, for example, clay-rich clods, reduce system performance because material at the centres of these clods are often cooler than at the surfaces. Unless emission controls have been specifically set up to deal with mixed contaminants, the presence of volatile metals at the applied temperatures can cause pollution control problems. The presence of significant amounts of soil organic matter (greater than 5-10 percent) may be a problem, since the concentration of contaminants within the reactor atmosphere must be below the explosion limit. Soils with a high pH may corrode internal systems.

Case study

Overleaf a case study is presented in the form of the flow charts presented in Volume 1. The objective of this is to demonstrate how the process illustrated on the flow charts works on a real site. Key information from each Phase is included for each box. Only key parts of the case study project have been included to illustrate the process.

The site was historically a metal processing works with a history of hydrocarbon, solvent and chemical storage and use. It is located within a mixed residential and industrial area. The site is located within a groundwater protection zone (GPZ) associated with a groundwater abstraction for potable use. A groundwater abstraction well is located 450m from the site and uses water from a Major Aquifer at depth which is overlain by a Minor Aquifer at the surface.

The Client was a developer who purchased a vacant site with the intention to redevelop it for residential housing. The consultant undertook a Phase 1 desk study followed by a series of progressively more targeted Phase 2 site investigations. Remediation design, implementation and verification were then undertaken.

The work was carried out to the satisfaction of the local authority and Environment Agency regulators and the site is currently occupied by residential flats and houses with private gardens. For the purpose of the flowcharts the main risks associated with hydrocarbons and chlorinated solvents have been selected and taken through the Phase 2 and 3 flowcharts. The increased understanding and refining of the conceptual site model, particularly with respect to potential pathways to the GPZ, is shown throughout the Phase 1 and 2 flowcharts. Extracts from sources of information used within the Phase 1 desk study, such as historical maps and geological cross sections have been included where they enhance the conceptual site model. Photographs showing investigation and monitoring techniques and remediation in progress have also been included.

Phase 1 Case Study: Hazard identification and assessment

1.1
Define objectives

To determine whether potentially contaminative uses have taken place within or in close proximity to the site which could have led to the contamination of underlying soils or groundwater.

1.2
Site definition and description

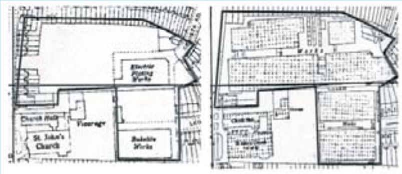
Previous reports, walkover, Envirocheck Report
Metal processing works – Bulk storage of TCE and hydrocarbons, small quantities of caustic chemicals and acids.

Is site area/boundary appropriately defined? NO → 1.2; YES ↓

Is site use/planned use appropriately defined? NO → 1.2; YES ↓

1.3
Determine site history

OS Maps
Metal processing works since 1930s. Gas works bordered to the south since 1870s.



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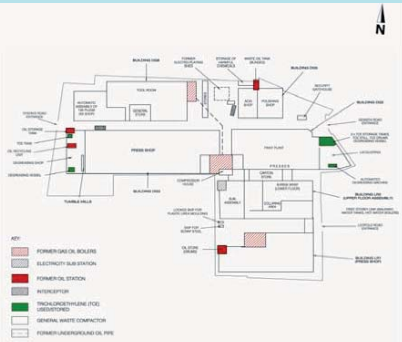
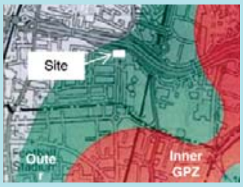
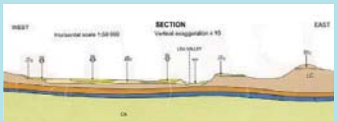
1.4
Determine current land use (storage/use/ disposal potentially hazardous materials)



1.5
Determine environmental setting

Envirocheck Report, BGS Boreholes and maps
Enfield Silts (Minor Aquifer); Kempton Park Grounds (Non Aquifer)
Reading Beds (Minor Aquifer); Chalk (Major Aquifer)
Pymmes Brook culverted along North boundary





1.6
Describe initial conceptual site model, (identify all potentially significant pollutant linkages)

Potential Sources	Receptors	Pathways
On-site Metal processing works – chlorinated solvents, hydrocarbons, metals, acids	Human Health – development workers, future site users.	Direct contact Inhalation of vapours
	Current and future buildings/services	Accumulation of flammable gases Acid attack on buried conc.
Off-site Gas works to South	Groundwater (Minor and Major aquifers)	Leaching/downward migration
	Surface water (Pymmes Brook)	Base flow/seepage

Data sufficient? NO → Carry out necessary further desk research → 1.2–1.5; YES ↓

1.7
Carry out Preliminary Risk Assessment

Potential Sources	Receptors	Pathways	Hazard [Severity]	Likelihood of Occurrence	Potential Risk
Former fuel storage – hydrocarbons	Future residents	Direct contact, ingestion	Human health **[Medium]**	**Likely:** Known fuel storage tanks since 1940s, potential for contact in garden areas.	**Moderate**
Degreasing – Cholrinated solvents	Groundwater (Chalk aquifer)	Vertical migration through low permeable strata to aquifer	Derogation of groundwater **[Medium]**	**Low likelihood:** Significant dilution, retardation, unknown thickness of low permeability strata	**Moderate / Low**

Have any potentially significant risks been identified?

NO → No further action → **Compile Final Report**

YES → **Progress to Phase 2**

1.1: Reference numbers in boxes refer to the relevant sections in the report.

Chart 2A **Phase 2 Case Study:** Risk estimation and evaluation

2.1
Define objectives of site investigation

To refine the conceptual model [geology, hydrogeology, and presence and nature of contamination] and establish the potential risks to future residents and environment.

2.2
Investigation design

- Soil probing using membrane interface probe (MIP) and laser induced. fluorescence (LIF) to assess hydrocarbons, chlorinated solvents. 29 locations to 8m
- 12 window sampling holes to 5m. Installation of 9 gas/vapour monitoring wells
- 10 deep boreholes to 15m, monitoring wells installed.

2.3
Identify appropriate investigation techniques

Site constraints/influences on SI techniques
Access restrictions and buildings: cut-down rig required.
- Gravels may restrict achievable drilling depth.
- Need to access presence and thickness of London Clay at depth.
- Need to monitor gases/vapours and sample groundwater.
- Aquifer protection required for deep drilling.

2.4
Sampling and Analysis Plan

Modifications during fieldwork
- Exploratory hole locations targeted areas of elevated solvents and hydrocarbons identified by probing.
- Response zones of monitoring wells placed in specific geological strata.
- Sampling groundwater dependent upon presence of LNAPL/DNAPL.
- Additional soil samples for chemical analysis due to visual/olfactory evidence.

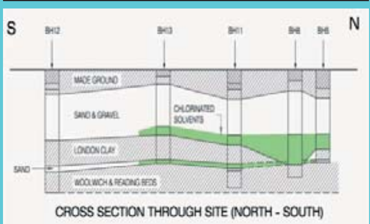
2.5
Monitoring

- Monitor groundwater in all deep boreholes once. Analysis: metals, pH, cyanide, sulphate, sulphide, chloride, DRO, coal tar, VOCs, sVOCs, phenol.
- Interface probe to measure free phase LNAPL/DNAPL.
- Gas monitoring on all wells on 5 occasions.
- Gas samples from two locations, analysed for VOCs.

Refine initial conceptual site model (CSM). Is it sufficiently well defined to allow GQRA?

NO (back to 2.2)

YES



2.6
Generic Quantitative Risk Assessment (GQRA)

Generic assessment criteria
Soil Guideline Values (soils) – elevated metals, hydrocarbons, phenol and VOCs.

Drinking Water Standards (Groundwater) – elevated solvents, PAHs, VOCs and hydrocarbons.

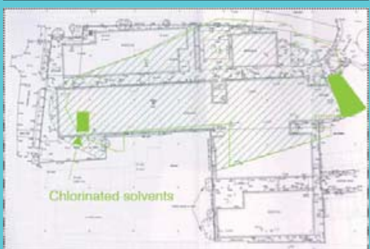
Are generic assessment criteria available/suitable?

NO

YES

2.7
Detailed Quantitative Risk Assessment (DQRA)

- London Clay thickness reduces to NE corner of site and is locally absent. Evidence of vertical solvent migration due to absence of London Clay.
- Areas of solvents delineated.



Site specific assessment criteria
Tier 3 groundwater risk assessment (R&D20) completed for solvents in groundwater migrating into Chalk Aquifer and to off-site abstraction borehole.

Acceptably low risk to abstraction well as long as chlorinated solvent and hydrocarbon concentrations in minor aquifer do not increase during development works (e.g. piling, removal of hard standing, earthworks).

2.8
Risk Evaluation

Unacceptable risks from hydrocarbon and chlorinated solvents (contaminated groundwater, soils and vapours) to:
- Human health (on/off-site).
- Damage to structures/services (explosion, corrosion).
- Groundwater (chalk, gravels) – during and post-construction.
- Surface water – during and post-construction.

Are there any unacceptable risks?

NO → No further action → **Compile Final Report**

YES

Would further detailed QRA help?

YES (back to 2.7)

NO

Progress to Phase 3

2.1: Reference numbers in boxes refer to the relevant sections in the report.

Chart 3A **Phase 3 Case Study:** Remediation; design, implementation and verification

Remedial options for chlorinated solvents:
- Air sparging
- Pump and treat
- Source removal (impact soils) with verification monitoring of groundwater

Remedial options for hydrocarbons (product):
- Pump and disposal
- Vacuum extraction
- Bioremediation

Selection influenced by low volume of product (~1000L), timescale. Source removal would reduce potential for migration during development works.√

Preferred option for chlorinated solvents:
- Source removal (impact soils) with verification monitoring of groundwater – requires post-development monitoring and comparison with remedial criteria.

Preferred remedial options for hydrocarbons (product):
- Pump and disposal – use of pumps to draw down groundwater in wells and attract product flow towards wells for collection and disposal.√

Regulatory Approvals

Verification criteria for chlorinated solvents agreed with regulators – groundwater monitoring for VOCs during development in 11 wells. If consistent 100% increase in chlorinated solvent measured over 3 months, additional groundwater treatment to be implemented.

Verification criteria for hydrocarbons agreed with regulators – product removal from wells for minimum of two weeks and until no physical detection (i.e. product thickness <5mm)

Soils
- Validation sampling of excavations; 1 per 25m² base, 1 per 5m² face.
- Validation criteria based on published thresholds for residential use.

Groundwater
- Measurement of product until product thickness <5mm.
- Monthly sampling of boreholes and Pymmes Brook during remediation and foundation construction.

3.1 Development of remediation objectives

3.2 Remediation Options Appraisal

3.3 Determination of remediation strategy

Has regulatory approval been obtained?

NO

YES

3.4 Implementation of remediation strategy

Are there any long-term requirements?

NO

YES

3.5 Long-term monitoring and maintenance

3.6 Verification

Compile Final Report

Contamination-related objectives:
- To ensure solvent concentrations in minor aquifer do not increase during development works.
- To ensure future residents do not have contact with contaminated soils or groundwater.
- To prevent vapours/gas accumulation in buildings/underground services.

Management-related objectives:
- To gain regulatory approval.
- To adopt cost-effective strategy.
- To complete 1st development phase within 6 months.

Engineering-related objectives:
- To avoid creating pathways for off-site migration.

Remediation of hydrocarbons

Three wells installed with skimmer pumps. Small volume of product recovered from only one well due to buried obstructions. Recovery trenches excavated and 250m³ oil impacted soils removed and disposed. Product on groundwater removed using absorbent mats in trench.

Remediation of hydrocarbons

Two areas of impacted soil removed followed by monthly verification monitoring groundwater in 11 wells at perimeter during development to check if deterioration to groundwater. Samples analysed for VOCs.

Long-term monitoring of groundwater
- Monitored natural attenuation of chlorinated solvent in groundwater; quarterly sampling of boreholes post-foundation construction for 18 months. Analysis solvents.
- VOC concentrations over 18 months post-development remained within pre-development range.

3.1: Reference numbers in boxes refer to the relevant sections in the report. Only key parts of the case study have been used to illustrate the process.

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