The Dynamics of the Development of Techniques for the Remedial Treatment of Contaminated Land.

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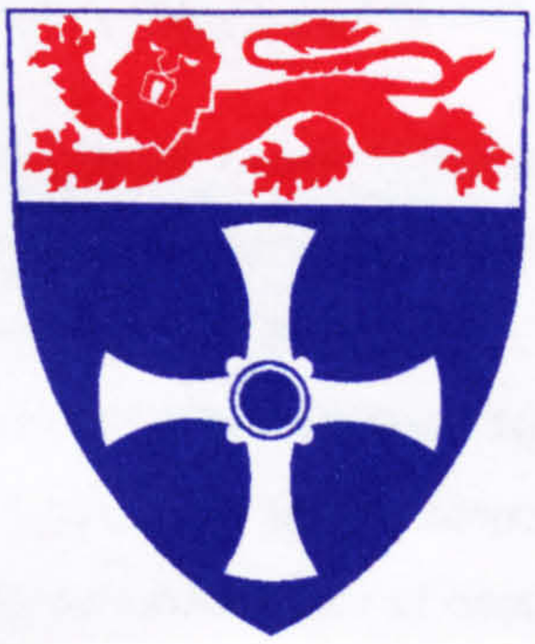

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ABSTRACT

The aim of this research is to investigate the process by which techniques for the remedial treatment of contaminated land evolve. This is accomplished through the study of the relationships between: environmental policy and law; industrial practice; and research and development. Previous studies of the barriers and driving forces of such development have tended to be from a technical point of view. However, this research aims to explore the *dynamics* of technological innovation.

Structured interviews, questionnaires and case studies were used to collect qualitative data from a cross section of the contaminated land industry. Interview transcripts were produced and subsequently, after consultation with the interviewees, presented as synoptic summaries including contextual information.

The interview, questionnaire and case study information is critically assessed with reference to relevant contextual information. The following areas are discussed: public opinion; regulation and policy; uncertainty and development; political lobbying; measures intended to stimulate the use of treatment techniques; and, the relationship between vendors, consultants and property developers.

It is concluded that: the development of treatment techniques is dependent upon the incremental accumulation of knowledge by politicians, scientists and the developers of remedial treatment techniques and that differences in these phenomena can result in "friction" in relation to the development of remedial treatment techniques. Particular emphasis is placed upon the adoption of pragmatic, deregulatory approaches to the regulation of contaminated land and the adoption of risk management approaches. It is emphasised that uncertainty relating to the performance of treatment techniques remains, particularly in relation to treatment time and cost. It is concluded that the commercial success of a treatment technique depends as much upon its ability to comply with the managerial constraints on the redevelopment process as upon its technical proficiency.

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GLOSSARY

AP	Appropriate Person
BATNEEC	Best Available Techniques Not Entailing Excessive Cost
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
CCLD	Department of the Environment Contaminated Land and Liabilities Division
CERCLA	The Comprehensive Environmental Response, Compensation, and Liability Act 1980
CLEA	Contaminated Land Exposure Assessment
COPA	The Control of Pollution Act 1974
DOD	US Department of Defence
DoE	UK Department of the Environment
DOE	US Department of Energy
DTI	UK Department of Trade and Industry
EA	UK Environmental Agency
EC	European Community
EIC	The Environmental Industries Commission
EIL	Environmental Impairment Liability
EPA	The UK Environmental Protection Act 1990
EU	European Union
GAO	United States General Accounting Office
HMIP	Her Majesty's Inspectorate of Pollution
ICRCL	Interdepartmental Committee on the Redevelopment of Contaminated Land
IPC	Integrated Pollution Control
JEMU	Joint Environmental Markets Unit
NIMBY	Not In My Back Yard
NRA	National Rivers Authority
OECD	Organisation for Economic Co-operation and Development

PL	Public Liability
PPG	Planning Policy Guidance
PRP	Potentially Responsible Party
RCRA	The Resource Conservation and Recovery Act 1976
RP	Responsible Party
SARA	The Superfund Amendment and Reauthorisation Act 1986
TIO	The USEPA Technology Innovations Office
UKELA	The United Kingdom Environmental Law Association
USEPA	The United States Environmental Protection Agency
WRA	The Water Resources Act 1991

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1. INTRODUCTION & OBJECTIVES

1.1 BACKGROUND TO THE RESEARCH

In light of high profile events such as Love Canal and Lekkerkerk, contaminated and derelict land has increasingly attracted the attention of the public and politicians alike. Estimates of the scale of the problem vary between 50-100,000 sites in the United Kingdom, covering an area of between 50-100,000 hectares (Ends 1991a). The actual figure may well be higher if the United Kingdom experience mirrors that found on the European mainland (Ends 1991c).

This stock of contaminated land has been caused not only by widespread ignorance of the effects of industrial activity but also by a failure of industry to internalise the external costs associated with contaminated land. As industry inevitably seeks to minimise costs, the only realistic solution to the contaminated land problem has to start with legislation. Although consumers may pay lip service to the need for a cleaner environment they are less willing to demand and seldom willing to pay for it directly (Turner et al. 1994). In addition, many of the external environmental costs involved may well have been caused many years ago by polluters that have long since gone out of business or who cannot be traced.

Considering the potential scale of contamination a structured approach is required to alleviate the greatest risks to health first and then progressively deal with the less serious sites (Young 1992). This is where CERCLA[1] and more recently SARA[2], the United States remediation programme commonly referred to as Superfund, experienced problems. By requiring stringent clean-up standards and by using a strict, retroactive, joint and several liability regime the process failed in the task of efficiently cleaning up contaminated land (GAO 1995, GAO 1997). However, despite this apparent failure a strong market for advanced remedial treatment has developed. This market serves the Superfund sites but more importantly it serves the less contaminated- though far more widespread- brownfield or derelict sites (USEPA 1995a).

The contaminated land provisions of Section 57 of the United Kingdom's Environment Act 1995 attempt to avoid the mistakes made in the United States by taking the wealth-creating sectors of the economy into account. It is intended that the redevelopment of contaminated land should occur as a part of the natural

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[1] *The Comprehensive Environmental Response, Compensation, and Liability Act*, PL 96-510, 1980. (CERCLA or Superfund)

[2] *The Superfund Amendments and Reauthorization Act*, PL 96-270, 1986. (SARA)

economic cycle. Furthermore, remediation should be to a level that makes the land concerned suitable for a proposed, rather than a multi-functional, use. Consequently, although *suitable for use* has the potential to promote the voluntary redevelopment of derelict land it could also prevent the development of a strong market for techniques for the treatment of contaminated land (Wilkes 1995; Wills and Jones 1996a). Furthermore, there are technical barriers to the efficient use of techniques for the treatment of contaminated land that are a result of the complex nature of land contaminants and the difficulties associated with their detection and remediation (Bardos 1991).

1.2 THE RESEARCH OBJECTIVES

The objective of this research was to investigate the nature of the process by which techniques for the remedial treatment of contaminated land evolve.

This was to be accomplished by seeking an understanding of the relationships between the following aspects:

- the objectives and effects of environmental policy and law;
- the criteria used by industry to select technology for commercial use; and,
- the research and development of techniques for the remedial treatment of contaminated land.

Essentially, the aim of this research was to demonstrate and consider the *dynamics* of the evolution and development of techniques for the remedial treatment of contaminated land.

1.3 JUSTIFICATION FOR THE RESEARCH

The barriers and driving forces of the use and development of techniques for the treatment of contaminated land have been studied by a number of authors (Section 2.6.7)(Crowcroft 1992; Sanning 1990; Smith 1991), as has the state of the art of such techniques (Bardos and Martin 1995).

Both Sanning (1990) and Bardos (1991 and 1995) deal with the development of treatment techniques and Bardos in particular has done much to review:

- the nature of the techniques available;
- their categorisation into biological, chemical, physical, solidification and stabilisation and thermal treatments;

- the identification of new treatment approaches and the enhancement of existing techniques; and,

- the identification of technical and non-technical barriers to the development of advanced techniques.

Furthermore, Martin and Bardos (1996) make a number of recommendations, based upon their work for the Royal Commission on Environmental Pollution, including the dissemination of information on treatment technologies.

However, and this argument is discussed in Section 2.7, the research of Bardos, Sanning and Martin has tended to concentrate upon the development of remedial techniques from a technical point of view with emphasis on the impediments to the use of remedial techniques. Crowcroft (1992), however, addressed the influences on the development of remedial techniques in a more holistic manner and also made reference to issues such as: policy and law, public awareness, boardroom or shareholder awareness and the "fear of being first". Phenomena, which included both technical and "cultural" influences were treated as both potential barriers and driving forces. This is the area this research explores in more depth, looking specifically at the *dynamics* of technological innovation. In this context *dynamics* does not refer to "the branch of mechanics that treats of motion in itself, and of the motion of bodies or matter under the influence of forces", as defined by the Concise Oxford Dictionary. It concerns the wider definition, also provided by the Concise Oxford Dictionary, which is a study, in any form of science, in which forces are considered, be they mechanical or moral. In this case, the forces which are considered are taken to be those which influence the evolution and development of techniques for the remedial treatment of contaminated land. Consequently, this research is not in the form of a typical geotechnical engineering thesis. It uses information obtained from interviews and case studies to review the wider influences on the development of techniques for the treatment of contaminated land.

Such a technique was employed by Jones (1991) in a review, commissioned by the Transport and Road Research Laboratory (TRRL), which considered the use made of reinforced soil techniques in the United Kingdom in comparison to other developed countries. The TRRL report was commissioned because although it was clear that significant economic and technical advantages could be achieved through the increased use of reinforced soil techniques in the United Kingdom, the techniques remained under-utilised. The review, in addition to a study of the use of reinforced soil in the developed world, called for a study of the factors which might affect decisions relating to whether to use reinforced soil or conventional construction techniques. These additional factors included:

I. Historical and cultural matters

II. The attitudes of clients, specifiers, designers and manufacturers

III. Perceived difficulties in design construction

IV. Available and improved design methods and their relative conservatism

V. Contractual and legal matters

VI. Other institutional inhibitions.

The report concluded that in addition to *perceived* technical concerns over the durability of reinforced soil techniques, the reluctance to use reinforced soil in the United Kingdom was "essentially cultural". Furthermore, although the recommendations of the report did refer to the technical barriers and a lack of information concerning the durability of reinforced soil in the United Kingdom, recommendations were also made concerning:

- the need for further education;
- the need to address organisational barriers to the use of reinforced soil;
- the need to address the conservative nature of many practicing engineers; and,
- the need for consistency in the use of terminology to avoid proprietary and legal problems.

This example provides an illustration that the influences on the use, and therefore, the development of civil engineering techniques are wider than the technical considerations alone. Thus, in order to study the use and development of civil engineering techniques an approach is required that includes factors other than those of a technical nature.

The information which formed the basis of the TRRL review was gathered by structured interview and questionnaire techniques. Although the interviews and questionnaires were conducted or completed by individuals, the information they gave was assumed to be representative of the organisations they represent. The justification for this is that the information they provided was framed in the context of the individuals own experiences. Experiences from a particular sector of industry. These opinions, rather that representing a bias, were considered important as they were indicative of the way in which different areas of the industry relate. By considering these opinions in the context in which they were given and comparing them with other sections of industry the "cultural elements" which exerted an effect on a situation were studied.

The work of Jones (1991) provides a precedent for the use of a phenomenological approach to the study of the use and development of civil engineering techniques[3]. This is the research approach used by this thesis to investigate the dynamics of the development of treatment techniques.

1.4 Definition of Terms Used

Throughout this thesis a variety of terms are used which are defined as:

Contaminated land does not refer to any precise legal definition. Rather, a wider meaning is taken from the NATO Committee on the Challenges to Modern Society (CCMS) which defined it as:

> "Land that contains substances which, when present in sufficient quantities or concentrations, are likely to cause harm, directly or indirectly, to man, to the environment, or on occasion to other targets." (Tromans and Turral-Clarke 1994)

Derelict, or **brownfield sites** are defined as:

> "Land so damaged by industrial or other development that it is incapable of beneficial use without treatment."[4]

The **treatment techniques** or **techniques for the remedial treatment of contaminated land** referred to in this thesis include techniques for the treatment of soil or groundwater. This definition excludes methods based purely on excavation, landfilling or containment, although, where these more traditional civil engineering techniques are combined with some form of treatment they are included. This definition is the same as the CIRIA definition for process-based methods which involve (Harris *et al* 1995b):

> "the application of physical, chemical or biological processes either to remove, destroy or modify contaminated sources or to remove or substantially modify the pathways along which contaminants may be released".

This is in contrast to the traditional **civil engineering methods** which CIRIA define as (Harris *et al* 1995b):

> "techniques either to remove the contaminant source, or to modify contaminant pathways without necessarily removing, destroying or modifying the source".

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[3] A useful definition of a phenomenological study is one which identifies empirical relationships for observed behavior starting from assumed operating processes (Terwindt and Battjes 1990).

The word **strict** is only used in relation to strict liability. Where regulations, that could be termed strict in the broader sense, are addressed they are termed **Draconian** or **stringent**.

1.5 SUMMARY

1.5.1 Chapter 1: The Introduction

The objective of this research was to investigate the nature of the process by which techniques for the remedial treatment of contaminated land evolve.

The introduction introduces the hypothesis that the development of remedial techniques is attributable to the interaction of the following factors, a situation which is illustrated in Figure 1:

- the objectives and effects of environmental policy and law;
- the criteria used by industry to select technology for commercial use; and,
- the research and development of new remedial techniques.

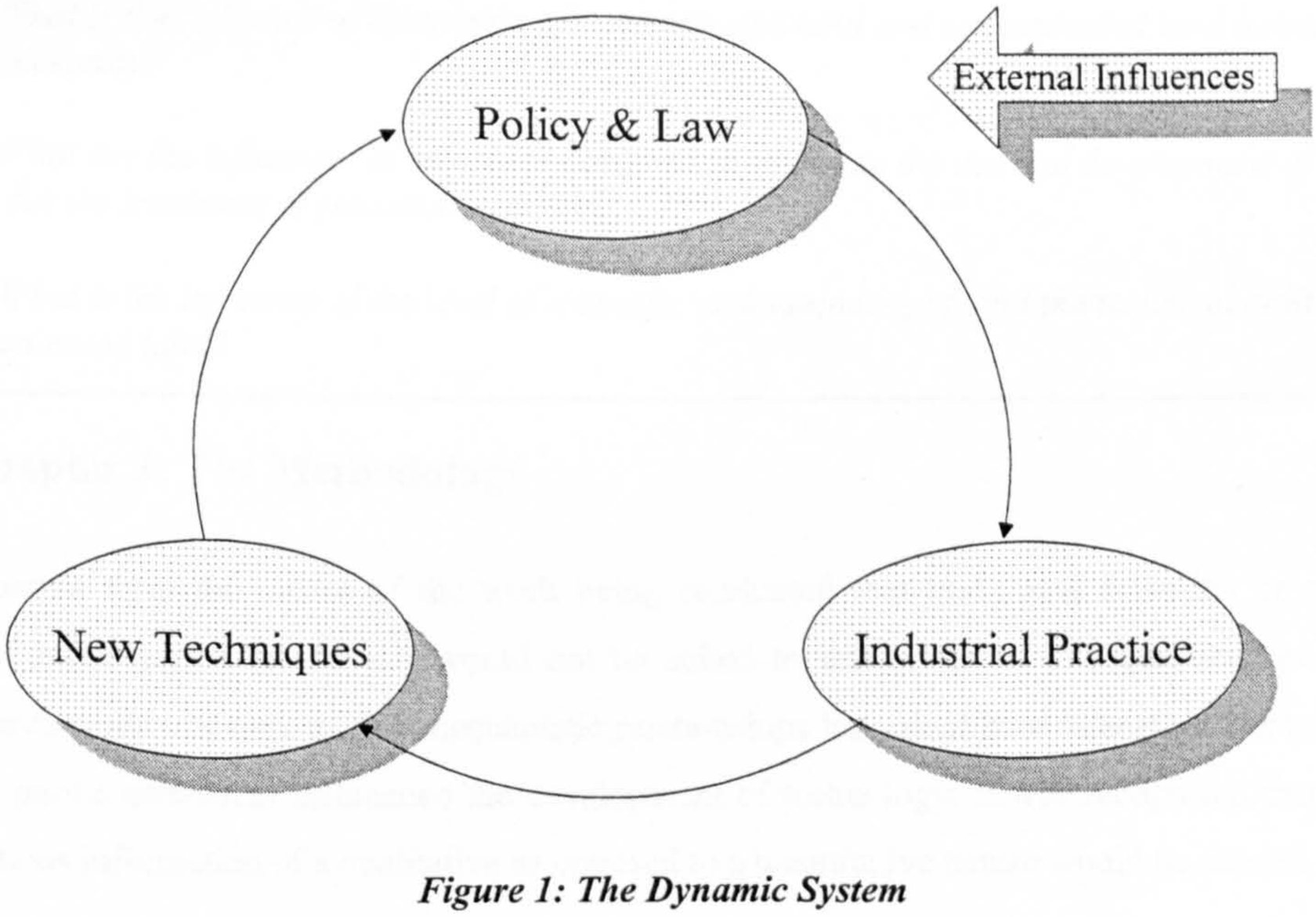

Figure 1: The Dynamic System

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[4] Department of the Environment, "Contaminated Land", Cm 1161, July 1990.

1.5.2 Chapter 2: The Research Issues

Figure 1 is a graphical representation of the situation this research seeks to explore, it also identifies "External Influences". The aim of Chapter 2 is to identify these influences and provide a theoretical foundation, based upon literature, for the study of the dynamics of development of techniques for the remedial treatment of contaminated land. Consequently, a range of disciplines were reviewed including: economic theory, environmental economics, environmental policy, the regulation of contaminated land, the provision of guidance on the redevelopment of contaminated land, the abilities of treatment techniques and their development and the development of strategies for the investigation and remediation of contaminated land. This provided a theoretical understanding of the dynamics of development of treatment techniques and facilitated the development of the research questions listed in Table 1.

Table 1: Research Questions

Question: What are the influences of policy instruments designed to address the problem of contaminated land?
Question: What is the influence of public opinion on the use and development of techniques for the treatment of contaminated land?
Question: What is the influence of awareness of contaminated land and contaminated land liability in the business community?
Question: What are the influences of measures designed to stimulate the use and development of techniques for the treatment of contaminated land?
Question: What is the influence of the level of scientific understanding of, and the technical ability to deal with, contaminated land?

1.5.3 Chapter 3: The Methodology

It was apparent from the nature of the work being conducted that traditional scientific or engineering methods of investigation or analysis would not be suited to this research. The questions posed by the literature review did not seek to find mechanistic relationships but asked how intangible elements such as the law or public awareness influenced the development of technology. It was recognised that to answer these questions information of a qualitative as opposed to a quantitative nature would be needed.

The qualitative nature of the information sought by this research made the development of a methodology an intriguing task. The unfamiliar nature of the research methods commonly used for the collection of such information meant that not only did the research methodology need to be selected and justified but also the reasoning behind these choices was required. After a careful study of such social science research procedures had been made, the Oppenheim (1992) system of research design was selected as the basis on

which to develop the methodology. Time restraints meant a decision was also made to design the research in a concurrent fashion. This approach enabled the research methodology to be adapted as experience was gained.

Structured interview followed up by questionnaires were selected as the primary form of information collection. The interview transcripts were written up as soon as possible after the event and verified with respondents. The findings of the earlier interviews were used to orientate the subsequent research.

During the process of the research it became apparent that despite efforts to ensure a representative cross section of the contaminated land industry, the owners and developers of contaminated sites were not well represented. Consequently, case study information, based upon the author's working experience, was used to supplement the interview information.

1.5.4 Chapter 4: The Results

Chapter 4 presents the information gathered in the interviews as a series of synoptic summaries. The aim of this is to provide a succinct account of the information collected and to demonstrate its validity both in terms of the influential roles of the individuals interviewed and the nature of the information collected from them. The opinions of 32 individuals from a variety of disciplines that together make up the contaminated land industry are summarised in this way. The information is in part specific to the problems of developing techniques for the treatment of contaminated land and in part contextual. 6 case studies are also presented at the end of the chapter with the aim of providing information relating to the owners and developers of contaminated sites.

1.5.5 Chapters 5: The Discussion

In Chapter 5, the influences on the dynamics of development highlighted in the interview information and the case studies, are explored. The phenomena which were identified in Chapter 2 are addressed and discussed in relation to the findings of Chapter 4.

In the discussion the rigid or arbitrary distinctions between the phenomena, as reproduced above, are less apparent. Essentially the boundaries between these influences merge as inevitably, the influences on the development of treatment techniques do not exist in isolation.

In **The Vagaries of Public Opinion,** the mercurial nature of public opinion is discussed with particular emphasis on the way in which risks can be perceived.

In **Regulation and the Development of Treatment Techniques** the influence of regulation on the development of treatment techniques is examined, particularly in relation to the difficulties in balancing

cost efficiency and effective regulation. In **Suitable for Use** this relationship is then further explored in relation to the development of the United Kingdom's approach to contaminated land. In addition, it is discussed how: the *suitable for use* concept illustrates a trend towards pragmatic forms of regulation which have developed from the existing planning system; and, how recognition of the inefficiencies of strict liability and stringent regulation in the United States and the Netherlands have influenced the development of treatment techniques. Finally, this section discusses the implications of such "pragmatic" policy choices on the potential for the development of treatment techniques.

Uncertainty & Development highlights the problems associated with developing treatment techniques in an uncertain policy environment where prevarication concerning the promulgation of environmental regulation represents a significant challenge. In **Lobbying & Regulatory Capture** the policy decisions concerning the Section 143 Registers and the landfill tax are discussed as examples of this prevarication and regulatory capture is suggested as a reason for these policy decisions.

The Stimulation and Verification of Treatment Techniques discusses the importance of validation in the development of treatment techniques and the relative success of initiatives such as the SITE and ETIS schemes are discussed. This section concludes with a profile of the types of technique that the interviewees believe will succeed.

In the final section of the discussion: **Vendors, Consultants and Developers,** a number of trends involving the relationships between the vendors of treatment techniques, the consultants that have the responsibility of advising on the remedial treatment of contaminated land and the developers of this land are discussed. This section draws upon the author's recent work experience of the contaminated land industry and pays particular attention to the practicalities of the remedial treatment of contaminated land and the selection of biological treatment techniques.

1.5.6 Chapter 6: The Conclusions

In **The Dynamics of Development** the usefulness of a revised view of the dynamics of development is discussed. It is concluded that a revised model illustrates the main influences on the dynamics of development but only to the extent that it facilitates general understanding.

In addition, it is discussed how the conclusions which are drawn are based upon the critical assessment of the literature, interview and case study information. It is emphasised, therefore, that the examples examined in the discussion and which form the basis of the conclusions are illustrative examples of the complex processes at work in the development of treatment techniques and not universal truths.

In the conclusions, emphasis is placed upon:

- the influence of the level of scientific, technical and political understanding of contaminated land;
- disparities in the levels of understanding of these phenomena; and,
- diverse priorities relating to the remediation of contaminated land.

It is concluded that:

1. Whether or not policy actively encourages the development of treatment techniques in a particular market, the development of treatment techniques is aided by continuity of approach, the development of standards and the publication of guidance.

2. The adoption of stringent regulations and prescriptive approaches to the remedial treatment of contaminated land in the United States and the Netherlands suggests lobbying on behalf of industry or landowners has not had such a significant effect on the development of contaminated land policy. Conversely, in the United Kingdom political lobbying has played a major role in the development of contaminated land policy, to the extent that a large market for treatment techniques has not developed.

3. The *suitable for use* concept represents a pragmatic, deregulatory approach to the regulation of contaminated land. However, policy decisions have and continue to be affected by vested interests and lobby groups. There is a fine line to be drawn between imposing Draconian measures on industry and adopting a laissez faire attitude.

4. Uncertainty relating to the performance of treatment technique remains widespread and limits their use, particularly in relation to the time and cost of the techniques. This situation is exaggerated by a reluctance on the part of consultant engineers and their clients to use untried techniques and who wish to be certain of the outcome of a programme of remedial action.

5. Successful treatment techniques in an increasingly mature policy environment will be those that can provide timely, economical and predictable solutions to contaminated, and importantly, brownfield sites.

6. The development of an apparently efficient treatment technique does not necessarily imply the technique will be a commercial success. Environmental consultants and their clients are justifiably reluctant to use treatment techniques which have not been demonstrated in the field. Consequently, for a technique to be used in a commercial situation the emphasis on attaining verification falls to the developer of the technique.

7. If the vendors of treatment techniques are to gain greater market share, and their techniques are to be used in a wider variety of situations, a change in the way the developers of contaminated sites conduct the redevelopments will be required combined with a greater willingness on the part of the vendors of treatment techniques to provide accurate time estimates.

The contributions of the thesis are stated as:

- The development of a model which facilitates the understanding of the complex process which influence the development of treatment techniques.

- A discussion of the dynamics of the development of treatment techniques.

These are illustrated by:

- An ability to provide a response to questions posed in a recent DoE Discussion Paper (DoE 1997).

- The publication of seven articles based upon the research.

2. RESEARCH ISSUES

2.1 OVERVIEW

The aim of this research was to provide illustrations of, and to illuminate, the dynamics of the process by which techniques for the remedial treatment of contaminated land evolve. The aim of this chapter is to provide a theoretical foundation, based on literature, for the investigation of this process. Consequently, this chapter draws on a range of disciplines.

In Section 2.2, the reasons for the difficulties involved in the allocation of environmental resources are outlined. Coase's theorem (Coase 1960) illustrates why problems relating to the allocation of environmental goods and services are not simply due to the failure of markets but also a problem of property rights and negotiation. In Section 2.3, the policy approaches used to address contaminated land in the United Kingdom and the United States are discussed and the problems with early regimes, which were based upon strict liability, are described. In addition, some of the solutions to the problem of regulating environmental concerns that have been suggested by economists and attempted by policy makers are described.

Section 2.4, after a brief account of the nature and origins of contaminated land, discusses the development of the United Kingdom's approach to contaminated land. The account includes the development of ICRCL, CIRIA and BS guidance and discusses the development of the United Kingdoms "pragmatic" risk management approach to the redevelopment of contaminated land.

Section 2.5 is a brief summary and discussion of the classification and selection of treatment techniques, a more detailed account of this information is provided in Appendix 6. Section 2.6 discusses how treatment techniques have been developed in the United States and the barriers and opportunities for the development of such techniques in the United Kingdom.

In Section 2.7, the chapter is reviewed and a number of issues that warrant detailed investigation are posed.

2.2 ECONOMIC THEORY & CONTAMINATED LAND

2.2.1 The Industrial Economy

Adam Smith, author of "An Inquiry into the Nature and Causes of the Wealth of Nations", is considered the greatest proponent of the industrial economy, the foundations of which are rooted in the industrial

revolution. In the mid to late 18th century new industry was being developed, driven by the power of productive capital. Smith said industrialists should have the freedom to make profits and generate wealth through the market, where, as by an "invisible hand" it would serve the common good for society as a whole (Ekins 1992).

The industrial revolution was a period of unprecedented growth and progress during which the promotion of industrial progress led to new interpretations of the law and to changes in institutional structure (Randall 1987). The laws of nuisance and legal standing were interpreted to encourage industry and resource use. Private law, essentially the law of tort and contract, served as a mechanism for the protection of interests in land rather than for protection of the environment. Industrialists enjoyed the freedom recommended by Smith even to the extent that they imposed costs on others, in particular those without the resources to fight legal battles or without any interests in land. Resource exploitation was encouraged so that the benefits could be transferred to those best able to use them (Ball and Bell 1991).

Arguably the most important element in the process of industrialisation was technological innovation (OECD 1985). Innovations such as the steam engine and the vacuum pump allowed the exploitation of fossil fuels to generate energy and the exploitation of minerals such as iron ore (Richards 1993). Simmons describes the situation thus:

> "The unprecedented transformation of energy into knowledge and thence into machines which in turn produce artifacts, some of which facilitate the manipulation of the natural world on a scale hitherto unimaginable". (Simmons 1989)

The technologies developed in this period of industrialisation concentrated on the exploitation of resources to generate wealth. The negative effects of contaminated land were not considered as important as the benefits that could be reaped by industrialisation. Remedial techniques were not developed as policy favoured the exploitation of resources over their conservation. Indeed, Randall (1987) is of the opinion that this growth was based upon a number of characteristics including the progressive and irreversible modification of land use and the release of agricultural and industrial wastes into the environment without any knowledge of their impact.

However, this does not imply that the effects of contamination were not felt, it was simply that policy makers did not consider them important enough to take into account. Innovation in the development of techniques for the remediation of contaminated land required a change in the emphasis of economic thought. Turner et al. (1994) discuss how such a change was first mooted when economists such as Malthus and Ricardo questioned the wisdom of Smith. They discussed the scarcity of resources, or the "absolute limits" concept, saying that a growing economy will use its most easily accessible resources first. Therefore, any future growth is offset by the increased costs of exploiting lower grade resources. These

early economists proposed no solutions to the problems they discussed, but they did recognise an imbalance and predict catastrophic consequences.

Easterlin (1974) developed the concept, proposed by Marx, that there is a social limit to growth. The Easterlin paradox, based on opinion poll evidence from developed countries, states that economic growth and increasing material wealth do not necessarily lead to an increase in happiness. A theoretical solution to this paradox is the no-growth or "steady-state economy". This poses the question- how big should the economy be allowed to be considering it is the human element of the environment as a whole? (Daly 1977). This modern period of environmental concern, or environmentalism, marks the time when contaminated land, along with may other environmental issues, first came to be considered an issue of any real importance. It was recognised that the inherited legacy of an industrial past had to be addressed and that the traditional forces of the market did not take account of environmental costs.

2.2.2 Environmental Goods & Services

Land can be considered a natural resource base that provides intangible goods such as amenity and areas of natural beauty. Similarly, the ability for land to assimilate contamination and its life support functions can be considered environmental services. The benefits of environmental goods and services, examples of which are listed in Table 2, are notoriously difficult to value (Turner et al. 1994).

Table 2: Environmental Goods and Services (After Turner et al. 1994)

a natural resource base;
a set of natural goods (landscape and amenity);
a waste assimilation capacity; and
a life support system.

Just as Turner *et al.* Argue that land, as an environmental good or service, is not always given its full value in terms of its external costs, it can also be argued that the commercial incentives for innovation in industrial practice and the development of remedial techniques can also be undervalued.

Turner et al. (1994) defined external costs as "unintentional side-effects of production or consumption that affect a third party". A negative external cost could occur when contamination migrates off a site and pollutes the environment to such an extent that local residents' health is affected, the locals having suffered an uncompensated loss of welfare. The commercial incentives for the development of remedial techniques can be undervalued as in practice, it is very difficult to assess the true costs of negative externalities,

particularly where the levels of pollution are small or are distributed over wide areas, due to the difficulty in evaluating environmental goods. This is the problem faced by remedial techniques for contaminated land as the benefits of such activities are difficult to see and the effects are difficult to quantify.

In situations where access to a resource is free or easy then its extraction or use can be so rapid as to threaten the existence of the resource itself. Open access, as this situation is known, occurs where there are no property rights or where such rights are easily challenged (Hotelling 1931). The ability of the environment to assimilate contamination is a good example of an open access environmental service.

Ayres and Kneese (1994) contend that air and water quality have not suffered from the problem of open access to the same extent as land as the effects of contamination on these environmental media are often readily apparent. Thus, they have received more public, political, commercial, and scientific attention. This could also be because economists have tended to deal with the effects on the environmental media of air, water and land separately, and hence, have underrated the effects of pollution on the environment as a whole and in particular in relation to contaminated land.

Market Failure to Include External Costs

The traditional view of the market mechanism says that a voluntary decentralised exchange process can, given the right conditions, determine an equilibrium price at which an efficient allocation of resources is achieved. However, the external costs of encapsulating contaminated sites are not addressed by the traditional market mechanism. The market mechanism is based on the price of a good, how much of that good consumers are willing to buy, and conversely, how much of that good firms are willing to offer for sale. It assumes, inter alia, that the full cost of production and consumption are reflected in market prices. This is an illustration of the inefficiencies of the traditional market system in relation to environmental goods and services. Correcting for externalities and the problems of open access in practice requires a set of government interventions in the market system via some combination of regulations and pollution taxes (Pearce et al. 1989).

Public Goods

Markets also fail to allocate scarce environmental goods and services because of the requirement that the goods being exchanged must, in principle, be individually owned. However, environmental goods and services, such as areas of natural beauty or the ability of a soil to attenuate contamination, are difficult to own- they are public or common goods. Menell and Stewart (1994) also provide the following definition of public goods:

> "Commodities that cannot be supplied to a given individual without at the same time enabling large numbers of other individuals to enjoy them simply because it is impracticable to exclude those other individuals from such enjoyment".

It is this nonexcludability that distinguishes public goods and often results in their exclusion from the market mechanism as consumers are not willing to pay the full price for a good for which others will receive some of the benefit. This is known as the free-rider problem. The remediation of contaminated land is a good example of this situation. Contaminated land and its potentially harmful effects are not desired by the public although the costs of remediating such contamination must ultimately either be passed on to the consumer in terms of increased prices or be externalised by industry. In the first case, the costs of production increase with the consequences this brings for levels of employment, productivity and prices. Turner et al. (1994) argue that this "publicness" is one of the reasons why markets do not naturally occur in environmental goods and services.

Coase's Theorem

It has been demonstrated above that, in theory, public goods suffer from externality problems. However, as the problems of contamination have largely been realised, the challenge, therefore, is not how to value externalities and take the problems of public goods into account, although cost benefit analysis does form a large part of the approach, but how to manage the change in policy and industrial practice that such a realisation must bring about.

Professor Coase, in his essay "The Problem of Social Cost", suggested a reason why remedial technologies are not employed, and the development of technology is stifled, is due to the problem of property rights (Coase 1960).

Coase's theorem states that the problems of collective goods, open access and externalities would solve themselves if it were costless to bargain. Coase argues that regardless of whether polluters have the right to pollute or whether victims have the right to be free from the effects of contamination, an efficient allocation of resources will result if the costs of negotiating a settlement are zero, see Figure 1.

However, applying Coase's theorem to the recent Cambridge Water case[5] (a situation where Easter Counties Leather Plc contaminated a groundwater supply used by The Cambridge Water Co. with the solvent PCE), Coase would argue that, in theory, the majority of the costs of remediating the pollution would be met by the victims of the contamination, i.e. the Cambridge Water Company. Conversely, in a

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[5] Cambridge Water Co. *v.* Eastern Counties Leather plc [1994] 2 W.L.R. 53.

situation where the users of the potable water supply that is at risk from contamination have a right to clean water, Eastern Counties Leather would bear most of the costs. The interested parties will negotiate a contract that brings about efficient resource use- sharing the benefits of this improvement in social welfare according to their respective bargaining power.

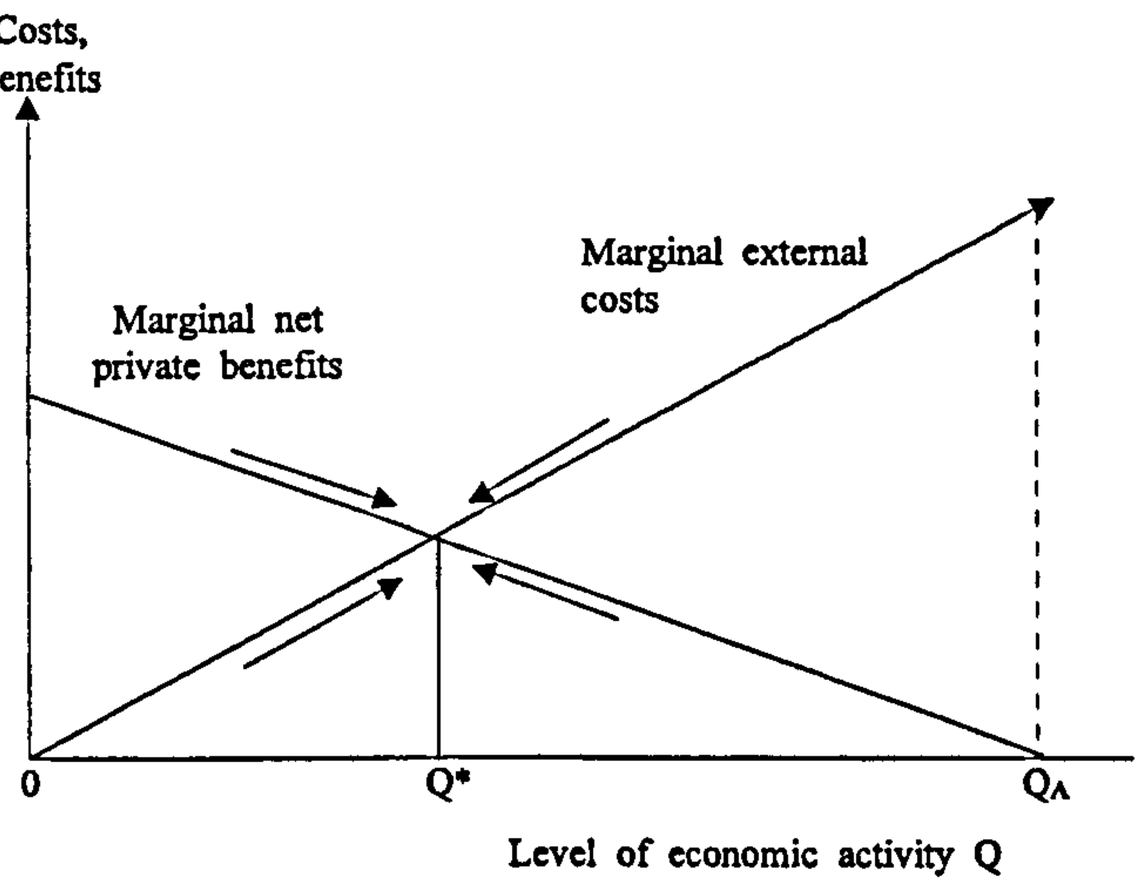

Figure 1: The Coasian Solution to Contaminated Land (After Coase 1960)

Importantly, Coase recognised that the problem with this analysis is that it assumes it is costless to bargain and that in the real world there are a number of problems that prevent the efficient resolution of negotiations, see Table 3.

Table 3: Factors That Prevent Efficient Negotiation (After Coase 1960)

Negotiation and litigation costs;
free-rider problems;
hold out problems; and
opportunism problems.

Coase illustrates that the reasons why externalities are not accounted for by the market are more complex than simply because they are difficult to value. Transaction costs complicate the situation, as do the legal entitlements of the parties involved. These factors create "friction" that prevents the efficient use of technology. This friction is well illustrated by the Cambridge Water case that went all the way to the House of Lords. A perfect illustration that the costs of bargaining are not zero!

2.3 THE REGULATION OF CONTAMINATED LAND

2.3.1 Love Canal, Lekkerkerk and Strict Liability

Between 1942 and 1953, 22,000 tons of chemical residues were dumped at the Love Canal site in Niagara Falls. The site was subsequently capped and sold to the Niagara Falls Education Board for the sum of $1 with the caveat that the site should not be disturbed by building works. Between 1953 and 1978 the restrictions relating to building on the land were ignored and in 1978, following a heavy rainstorm: large foaming pools of coloured liquid welled up through the ground; areas of ground opened up; and, children and dogs suffered chemical burns to their feet after playing in nearby fields. The levels of pollution found at the site were 5000 times higher than permitted safety standards. Hazardous substances were found in surface water, groundwater, soils, the basements of homes, sewers, creeks and other locations surrounding the site. Medical tests showed that residents had much higher than average levels of cancers, liver disease, miscarriages and retarded children. A state of emergency was declared, 900 families were evacuated and their homes demolished. Clean-up costs at the time totaled $13 million. Subsequent litigation costs have reached £3 billion (Anon 1994; LaGrega et al. 1994; Wentz 1995).

Between 1972 and 1975 houses were constructed on a reclaimed site in the small Dutch town of Lekkerkerk. In 1980, 1,600 drums of illegally dumped toxic waste were discovered. The waste consisted of chemicals from the dyestuffs industry and caused contamination of drinking water and underground void space. The area was evacuated and remediated in 1981 at the cost of £156 million (Luigies 1991).

The Love Canal and Lekkerkerk incidents occurred at a time when the remedial treatment of contaminated land was not a common activity, although not unheard of. Authors such as Luigies (1991) La Grega *et al* (1994) Wentz (1995) and Tromans and Turral-Clarke (1994) have argued that these events have had a significant influence on the regulation of contaminated land at the time when regulations to deal with the contaminated land were being developed. The general consensus amongst these authors is that political reaction to public outcry as a result of these events encouraged the adoption of Draconian regulation.

In the Netherlands, the Soil Clean-up (Interim) Act 1982, was introduced to address the problem of contaminated land (Tromans and Turral-Clarke 1994). Evaluations and clean-up are undertaken at the expense of the government. There are provisions for the costs to be recovered from those parties held responsible (Luigies 1991).

Under CERCLA, and later SARA, the United States Environmental Protection Agency (USEPA) were granted the power to investigate and clean-up contaminated land. The funds for the remedial action was to

come from the "Superfund", set up by Congress and "Responsible Parties" (RP). "Potential Responsible Parties" (PRPs) are defined as:

- the past and present owners or operators of a site;
- parties who transported waste to a site; and,
- parties (generators) who arranged for waste to be disposed or treated at a site.

Superfund is one of the most radical pieces of legislation ever adopted by the United States Congress as it introduces strict, retroactive, joint and several liability. The USEPA were granted the power to take action against one or all of the above with an equally weighted responsibility and because liability is strict there is no need to prove fault (Brumund 1994).

The adoption of such Draconian forms of liability suggest that Superfund was employed primarily as a political measure, the "command and control" statutes often mandating stringent goals, deadlines, and strict liability (Jacoby and Ermich 1991). Consequently Luken and Fraas (1993) contend that the United States has developed a combative regulatory system, the effect of which has been the development of an increasingly compliance-oriented business community and an increase in the annualised costs of environmental regulation related activities. Indeed, such costs rose from 0.9 to 2.1% of GNP between 1972 and 1990.

Thompson (1991) suggests that a similar politically motivated move towards strict liability has also occurred in Canada where legislation has created wide-ranging responsibilities for the owners and occupiers of property. Thompson argues that environmental liability is now apparent in business and real estate transactions with its consequences being felt by lenders and their agents.

Klots and Siakotos (1987) cite several reasons, based upon research in the United States, why strict liability can cause problems:

- environmental laws impose such extensive liability that they are a threat to the solvency of borrowers;
- lenders may be directly liable for costs and damages if they rely on their security and take title to contaminated property;
- lenders may be vicariously liable as a result of their indemnification of agents employed to realise on their security; and

- increasing public concern over environmental protection will see the increasing implementation of tougher legislation that will prove to be onerous on lenders.

These issues also have international connotations. Indeed, in 1995 the British insurance market was reported to be in a state of panic over £8 billion of losses incurred in the United States relating to contaminated land and how this may only be the tip of the iceberg (Anon 1995a). Their concern was heightened as such retroactive policies were also finding favour in Europe in the form of a Green Paper "Remedying Environmental Damage", that suggested civil law in Europe should be harmonised on a regime of strict liability (Heyes 1994).

However, while the German and Dutch governments were pushing the case for strict liability in Europe their position was opposed by the United Kingdom which favoured a more negligence based standard, a position that had previously been challenged by the European Commission as a failure to implement correctly the Consumer Protection Act 1987 (Burnett-Hall 1993).

Renner and Johnson (1995) state that this opposition to the use of strict liability in the regulation of contaminated land is also apparent in the United States where there are moves afoot to reform Superfund as strict liability and stringent clean-up standards are increasingly considered at odds with the efficient remedial treatment of contaminated land. The reaction of industry to Draconian regulation and strict liability has been to contest liability rather than be faced with large remediation costs. Indeed, one of the main stumbling blocks in the reauthorisation of Superfund has been the issue of retroactive liability.

Heyes (1994) contends that for strict liability to incentivise industry to prevent pollution it relies on two misleading notions:

- that a strict regime necessarily generates a greater incentive for prevention than does a fault-based regime, and

- that more prevention is always and everywhere a desirable thing.

Where there is uncertainty as to whether a plaintiff can demonstrate the reasons for their alleged contamination related health problems the expected liability of a polluter under strict liability is reduced. However, with a fault based system the prospective polluter or owner of a known contaminated site continues to avoid liability by respecting the required standard of care (Heyes 1994).

On September 30 1994 the Superfund programme expired. Industry, environmentalists and scientists saw this as an opportunity for reform and proposals were made to alter the stringent clean-up standards for groundwater, standards that the National Research Council found were only reached in 10% of cases

(MacDonald and Kavanaugh 1995). However, Congress disagreed over the nature of the reforms, and thus, the fate of Superfund is still to be decided (Anon 1995b).

2.3.2 Policy Solutions

Economic Incentives

As population, resource utilisation, and income have increased, society has demanded increasingly stringent environmental standards. Hahn (1993) contends that as a consequence of these demands the costs of pollution control and the intrusiveness of regulation have increased based upon command and control (CAC) forms of regulation. Economists however favour an approach based upon economic incentives because they believe government can develop more flexible rules and regulations that can achieve better environmental quality at a lower total cost.

Economic incentives require some form of cost benefit analysis and the central modification of markets where the value of environmental goods and services are decided centrally and then incorporated into the prices of goods and services (Turner et al. 1994).

Prima facie, economic incentives can operate efficiently as they equalise the level of marginal pollution abatement costs among firms and therefore provide an incentive for cost effective clean-up and investment in new technology. However, their application is often sub-optimal and can be hindered for the following reasons (OECD 1989):

- economic incentives tend to be set at too low a rate to achieve the objectives of the regulators, and
- economic incentives tend to be introduced in conjunction with direct, CAC style regulation.

Pollution Taxes

The taxation of pollution was first mooted in 1920 by Pigou (Raja and Smith 1993). Pigou suggested that polluters should face a tax equivalent in value to the damage they cause to the environment. However, for such a tax to be efficient it must reflect the costs of pollution. As has been discussed above, it is difficult to assess accurately the true cost of pollution at the margin, a number of proxy solutions, such as charges or permits, are commonly employed by policy makers.

Economists consider pollution taxes to offer an advantage over traditional CAC regulatory approaches in relation to the stimulation of treatment techniques because taxes are flexible. Taxes can provide incentives for the development of new technology if they are initially set at a low level and steadily increased, thus, in

theory they can allow an iterative or frictionless approach to change. However, as the accurate calculation of a pollution tax is unrealistic, the best that can be achieved is an acceptable compromise in the face of imperfect information (Pearce and Turner 1990).

The United Kingdom's Landfill Tax was proposed for introduction in 1996. By taxing the disposal of contaminated land to landfill, alternative techniques could have been encouraged. Such techniques could be developed from other industries, such as chemical engineering, or imported from overseas where the techniques have already been developed. The Landfill Tax offered the opportunity to promote substitutes to encapsulation that have been prevented from competing because of price levels (Ends 1995a). Table 4 illustrates the price barriers new remedial techniques have experienced in the United Kingdom.

Table 4: The Relative Costs of Remedial Treatments for Contaminated Land (1992) (After Crowcroft 1992)

System	Typical Unit Cost
Landfill of Hazardous Waste	£7-20/ton
Capping	£20-30/m^2
Dispersion by Chemical Reaction	£20-60/ton
Soil Flushing	£25-70/ton
Kiln-based Vitrification	£30-50/ton
Biological Treatment	£30-50/ton
Vertical Slurry Wall	£30-60/m^2
Vacuum Extraction	£40-50/ton
In-situ Vitrification	£150-215/ton
Thermal Treatment	£50-750/ton

2.3.3 Setting Environmental Standards

Despite the opinion of many economists that economic incentives are a more efficient form of regulation than CAC related standards, Turner *et al.* (1994) contend that most governments still favour CAC because:

- less detailed information is required to introduce regulations; and,

- prespecified policy targets are easy to achieve.

Industrialists also tend to favour a CAC approach as established firms within a regulated industry can experience the benefits of regulatory capture. This concept refers to the tendency for regulators and industrialists to seek common ground and co-operation, as has been the case in the United Kingdom where a co-operative approach to the enforcement of environmental laws has been pursued in the past. A specific example being the Control of Pollution Act 1974 which created a system of regional waste disposal authorities with the responsibility of operating sites themselves and at the same time regulating private sites by means of the licensing system. The inherent conflict between the nature of their administrative duties and the regulatory functions proved to be the foundation of many difficulties. The perception that the WDAs were acting as both "poacher and gamekeeper" sought to undermine confidence in the waste disposal industry in the public at large (Ball and Bell 1991).

The concept of regulatory capture suggests that, once "captured", policy makers and regulators perceive a need to protect their relationships with existing members of an industry for fear of causing alienation. Regulators therefore allow a certain amount of infringement provided working relationships are not abused and policy makers regulate in such a way as to maintain the status quo. Thus, new entrants to the market are excluded because of these "subsidies" offered to the existing members of the industry. Therefore, CAC policies tend to reduce the incentives for innovation or improvement beyond the targets set and generally translates into inefficient resource use (Turner et al. 1994).

A possible solution to this problem is to search for feedback mechanisms that reward resource conservation and environmental improvement. However, if economic incentives are to succeed their implementation depends upon a number of pragmatic considerations. It is critical that, as well as being efficient, the policy package is equitable, administratively feasible, dependable and provides dynamic and continuing incentives for improvement (Young 1992).

2.3.4 The Environmental Agenda in the 1990s

Young (1992) describes a trend towards improved environmental planning and management with the emphasis on long-term considerations with the aim of providing better ambient environmental standards, reduced risks to human health and more cost-effective pollution control.

The efficient environmental agenda in the 1990s includes the following tenets (Young 1992):

1. the **polluter pays principle** to force those creating the pollution to pay the costs of meeting socially acceptable environmentally quality standards;

2. the **prevention or precaution principle,** which explicitly recognises the existence of environmental and social uncertainties and seeks to avoid irreversible damage via the imposition of a safety margin, in the form of safe minimum standards, into a policy; it also seeks to prevent waste generation at source, as well as retaining some end-of-pipe measures;

3. the **economic efficiency or cost-effectiveness principle,** applying to the setting of standards and the design of the means (policy instruments) for attaining them;

4. the **subsidiarity principle,** to assign environmental decisions and enforcement to the lowest level of government capable of handling them without significant residual externalities; and

5. the **legal efficiency principle** to preclude the passage of regulations that cannot be realistically enforced.

This way of considering the problems of the environment is often referred to as ecological modernism. It involves looking at environmental problems in a holistic manner with the view of achieving environmental protection in the most efficient way (Weale 1993). This view of environmentalism is illustrated in the United States by the reform of the USEPA and Superfund, where an unlikely partnership has been struck between environmentalists and industrialists who recognise that strict liability hinders the remediation of contaminated land and prevents innovation (Andrews 1995; Anon 1995b). As a part of the Clinton Administration Regulatory Reform Initiative, President Clinton emphasised the need to reform environmental policy and move away from prescriptive forms of regulation and toward increased "flexibility" (Clinton and Gore 1995).

2.3.5 This Common Inheritance

The concept of ecological modernism is also contained within the EC Environmental Action Programmes that began in the early 1970's. It states that environmental protection should not be regarded as a burden on the economy but a precondition for sustainable economic growth and that a clean environment and economic feasibility should not be seen as conflicting ideologies (Weale 1993).

The concept grew out of the need, recognised by liberal democracies, to pay attention to the needs of the environment in an holistic way. Environmental protection has implications for the working of the economy and as such policy makers began to see the problem as one of market failure and that this had to be addressed. Initially, the EC regarded this as a failure in relation to members' quality of life caused by a reliance on national income accounting- a method that does not measure economic welfare effectively.

However, by the 1980s this had changed to a regard for the protection of the environment as a goal in itself. Ecological modernism had become a means to attempt to combine economic feasibility and environmental protection (Johnson and Corcelle 1989).

There are two factors at work that provide the regulatory framework for the control of pollution: law and policy. Law acts as a link between statutory guidance and control in specific situations. Legislation related to the regulation of pollution tends to provide procedures to be applied in a case specific basis. This approach is used due to the complexity inherent in most developments that precludes predetermined solutions (Grant 1994).

The British Government outlined ecologically modern policies in the White Paper "This Common Inheritance"(DoE 1990b), which states its objectives are to:

- prevent pollution at source;
- minimise the risk to human health and the environment;
- encourage the most advanced technical solutions that can be cost effectively applied; and
- apply a critical load approach to pollution, in order to protect the most vulnerable environments.

Legislation based upon these policy objectives was introduced in the form of: the Town and Country Planning Act 1990; the Planning and Compensation Act 1991; Parts I and II of the Environmental Protection Act 1990 (EPA); and, the Water Resources Act 1991.

Examples of the policy instruments this legislation introduced include: the Duty of Care, introduced in the EPA part II; Integrated Pollution Control (IPC); Best Available Technique Not Entailing Excessive Cost (BATNEEC); and, Best Practicable Environmental Option (BPEO), all introduced in the EPA Part I.

2.4 Approaches to Contaminated Land

2.4.1 The Nature of the Problem of Contaminated Land

A number of introductory texts have been written on the nature of the problem of contaminated land. These explain (Harris *et al* 1995b):

- the origins and evolution of contaminated land;

- the main types of hazards which are likely to be encountered on contaminated sites; and,
- the principal potential impacts associated with the presence of contamination.

The most common causes of contaminated land are described below. The hazards and principal potential impacts of contaminated land are dealt with in Section 2.4.2.

The Origins and Evolution of Contaminated Land

Contamination may arise from a variety of activities. This could be due to the intentional deposit of material on land, be this as a means of disposing of that material, or in connection with development or construction activities. For example (Tromans & Turrall-Clarke 1994):

- landfill sites;
- tips;
- lagoons for industrial effluent;
- deposits for dredgings;
- made ground and filled dock basins; and,
- the deposition of sewage sludge on agricultural land.

Another category is contamination arising incidentally in the course of industrial activity including:

- spills and leaks of materials from storage tanks and drums;
- escapes of materials such as dusts and liquids in the course of the activity itself; and
- contamination resulting from deposition of airborne particles.

A further possible cause of contamination are lax practices during decommissioning and demolition of industrial facilities.

Early studies into the contaminated land in the United Kingdom enabled the development of lists of those particular types of industrial, or other activity, which appear to be frequently associated with land contamination. One of the first studies into this subject to be carried out in the United Kingdom was by ECOTEC and Liverpool University for the Welsh Office and the DoE. In a memorandum submitted to the House of Commons Environment Committee, the Welsh Office referred to this survey of 746 contaminated

sites. Atwell (1993) reproduced this list, which is given below and combined with similar lists by Young *et al* (1997) and Parry and Bell (1987):

1. **(Former) public utilities and transportation,** which include old gas-works, coal carbonisation plants and ancillary by-product works, power stations, old sewage farms and works (where the concentrations of metals in the soil may be high), railways and sidings, dockyards, canals, roads, airports and any former hospital sites.

2. **Processing of primary minerals,** examples of which are asbestos works, smelters, foundries and metal finishing works.

3. **Chemical process works,** especially oil refining, storage and distribution, pharmaceuticals, ceramics, plastics, paint, solvents, chlorinated sludges, materials containing PAHs, wood preserving, paper, textiles, tanning and munitions.

4. **Mineral extraction and subsequent landfill,** including quarries, gravel pits, deep and opencast coal mines and clay pits.

5. **Metaliferous mining** of ores of iron, tin, lead, copper and zinc.

6. **Miscellaneous categories** such as scrap yards, the storage of bulk waste such as pfa, lime or chromate waste, munitions factories, old processes such as gelatin works and creosote manufacture.

It should be noted that this list is not means exhaustive, it represents those industrial uses that are considered to be the most contaminative.

In comparison with its counterparts in the United States and the Netherlands, the Government of the United Kingdom has been relatively slow to develop a regulatory regime to deal specifically with contaminated land. Incidents such as the Love Canal and Lekkerkerk stimulated the development of regulatory regimes in the United States and the Netherlands. These incidents, in combination with the Loscoe incident in Derbyshire in 1986 where methane gas from a landfill site destroyed a bungalow, prompted the British Government into action in the late 1980s and early 1990s (Tromans and Turral-Clarke 1994). However, despite this lack of specific legislation, the need to reclaim contaminated land became an issue in the mid to late 1970s when certain Local Authorities began to experience problems in relation to the redevelopment of particular sites which were contaminated as a result of their former use (Haines 1987). Early reclamations, such as that at Thamesmead, the former Woolwich Arsenal (Lowe 1979) and Beaumont Leys Sewage Farm, Leicester (Heeps 1982) encountered a number of difficulties arising from the presence of toxic substances which had resulted from previous land usage. In these cases, large scale residential

developments had been planned and this prompted these Local Authorities to approach central government for advice on how best to approach these sites (Harris 1987; Heeps 1979).

Similarly, an illustration of the growing importance of contaminated land as a result of high profile events such as Love Canal is that the work of institutions such as the American Society of Civil Engineers (ASCE). In June 1977, and in recognition of the growing importance of disposal fills and the use of solid waste in geotechnical practice, the ASCE held a conference on "The Geotechnical Practice for Disposal of Solid Waste Materials (ASCE, 1977). The conference dealt with the geotechnical aspects or problems common to the disposal of all types of solid waste, and although the major emphasis of the conference was on:

a) the geotechnical properties affecting disposal and utilisation of solid waste;

b) the utilisation of solid wastes in dams, embankments and as structural fills; and,

c) the problems of leachates and gasses produced from landfill, tailings lagoons and dredgings-

the conference also focussed to a limited extent on the reclamation of contaminated soils. Included in the section on dewatering, stabilization and reclamation were treatment techniques such as the in-place treatment of cyanide contamination by using a strong solution of sodium hypochlorite (Katsman and Zimmerman 1978) and the chemical treatment of PCB contaminated river dredgings from the Hudson River (Zimmie and Tofflemire 1978)

2.4.2 The Inter Departmental Committee for the Reclamation of Contaminated Land (ICRCL)

Initially the Local Authorities involved with the reclamation of the British sites approached the DoE and the Department of Health and Social Security. In response to these inquires and in foreseeing that pressure to redevelop old industrial areas for housing or amenity would increase, in 1976 the ICRCL was set up to co-ordinate advice on contaminated land. The committee included representatives from the DoE, the Department of Health and Social Security, the Welsh Office, the Health and Safety Executive and the Ministry of Agriculture, Fisheries and Food. The ICRCL had four main work areas (Harris 1987):

1. To provide information to Local Authorities and private developers dealing with contaminated land.

2. To publish information which could guide developers. This has resulted in the publication of guidance on:

- gasworks (ICRCL 1978);
- landfill sites (ICRCL 1978);
- sewage works (ICRCL 1979);
- scrap yards (ICRCL 1980); and more generally in relation to contaminated sites,
- contaminated land (1983);
- fire hazards (ICRCL 1983);
- asbestos (ICRCL 1985).

3. To initiate research into areas of contaminated land where little was known or understood which, inter alia, involved the study of (Harris 1987):
    - The behaviour of contaminants under certain types of remedial treatment in relation to metal uptake by plants.
    - Engineering methods of reducing metal levels in the soil.
    - Problems of contaminant migration.
    - Performance of past reclamations.
    - The combustibility of fill materials
    - The problems created by methane.
    - A review of in-situ treatment options.
4. To bring the subject into open debate. In 1978, the ICRCL was involved in the organisation of The Society of Chemical Industry Conference: "Reclamation of Contaminated Land" (Society of Chemical Industry 1980).

Furthermore, in addition to its involvement in the provision of advice to Local Authorities and others with an interest in contaminated land, the ICRCL had been involved in work with direct relevance to its own purpose. Two important examples are: the NATO/CCMS (Committee on Challenges to Modern Society), see Section 2.6.5, and the preparation of the BSI draft Code of Practice on the Identification and Investigation of Contaminated Land (BSI 1983).

The definition of contaminated land was that given in the original BSI Code of Practice in 1983 defined contaminated land as:

> "Land that contains any substances that when present in sufficient concentration or amount present a hazard. The hazard may:
>
> 1. be associated with the present status of the land;
> 2. limit the future use of the land; and
> 3. require the land to be specially treated before particular use."

However, such definitions began to receive criticism and specifically as being so general as to be unhelpful in practice (Beckett and Simms, 1984), although this was the reason of issuing the draft Code of Practice. The response to this draft Code of Practice included comments by authors such as Lord (1983 and 1987) and Cottington (1984) who advocated a logical sequence of site investigation incorporating a blend of scientific necessity and economic viability. Specifically Lord (1983), advocated five distinct stages:

1. Recognition that an investigation is needed and the establishment of the basis for that investigation.
2. Design of a site sampling/analytical programme.
3. On site sampling, observation and testing.
4. Analysis of the materials taken from the site.
5. Interpretation of analytical data.

Following this consultation exercise, the draft Code of Practice DD 175, was published in 1988 (BSI 1988). In addition to the review of the BSI Code of Practice, the guidance given by the ICRCL also underwent modification as new information on how best to develop contaminated land evolved. Specifically a new operational definition of contaminated land was proposed (Beckett and Simms, 1984):

1. Land which because of its former uses now contains substances that give rise to the principle hazards likely to affect the proposed form of development, and which
2. requires an assessment to decide whether the chosen development may proceed safely or whether it requires some form of remedial action, which may include changing the layout or the form of the development.

This new definition was suggested by the ICRCL in response to the inadequacies in the previous definition which had led to "over-reaction" and a lack of attention as to how the possible risks can be assessed and hence avoided or overcome (Harris 1987). This new definition was drawn strictly within the context of redevelopment and with a strong reference to the need for the critical assessment of the site in relation to the proposed development. The definition also refers to the fact that remedial action can include changing the form or layout of the development.

Another area developed at this time, the results of which are listed above, was the provision of guideline information on levels of contaminants in soils. This guidance was of value to Local Authorities who needed to make decisions with relation to the development of contaminated land. Between 1979 and 1983 the ICRCL issued a number of guidance documents. The advice given by the ICRCL has always been of a tentative nature although the terminology, content and presentation has changed. Early guidance used the argument of "acceptable" levels of contaminants in which three different scenarios were envisaged. If, after a thorough site survey, observed contaminant levels were found to be below the guideline for the particular use then it could be assumed that the presence of the contaminants posed no significant hazard to critical groups and no subsequent action would be required. If, however, observed levels slightly exceeded the guidelines then the situation was considered "undesirable". In such situations, it was considered appropriate to consider to what extent, if any and taking into account all available information, what remedial action should be taken. At some higher level of contamination the situation was considered "unacceptable" and therefore appropriate remedial measures would be essential for the particular use. The guidance issued prior to 1983 did not attempt to define any level of contamination other than the "acceptable" level but suggested that there was a need to use professional judgement and expertise in those situations where guideline levels were exceeded.

In May 1983 with the publication of the ICRCL 59/83: Guidance on the Assessment and Redevelopment of Contaminated Land, a revised form of advice using a different terminology and a revised format was introduced. Guideline information is presented in the form of "trigger concentrations" which, combined with the natural background level, are intended to be of assistance during the interpretation of data derived from site investigation. As before, three situations are provided. When observed levels of contamination are below the trigger concentration value, the site can be regarded as being uncontaminated in so far as the contaminants pose no additional risk to the critical group. ICRCL 59/83 states:

> "If the trigger concentrations are not greatly exceeded, remedial action is not automatically required. At some still higher concentrations the risks posed by the presence of contaminants might be judged unacceptable for a particular use. Remedial measures appropriate to that use would then become essential or another use, less 'sensitive' to the contamination would have to be adopted."

In this method of interpreting site investigation data, which is illustrated in Figure 2, the trigger concentrations represent a value at which consideration should be given to the presence of the contamination: professional judgement and experience are then to be used to decide whether or not remedial action is necessary. The guidance does not assume that if the guideline levels are exceeded that a site is dangerous, unusable and therefore requires remediation - it assumes that such action is required if the development of the site cannot be modified in such a way as to reduce risks presented by such hazards to acceptable levels.

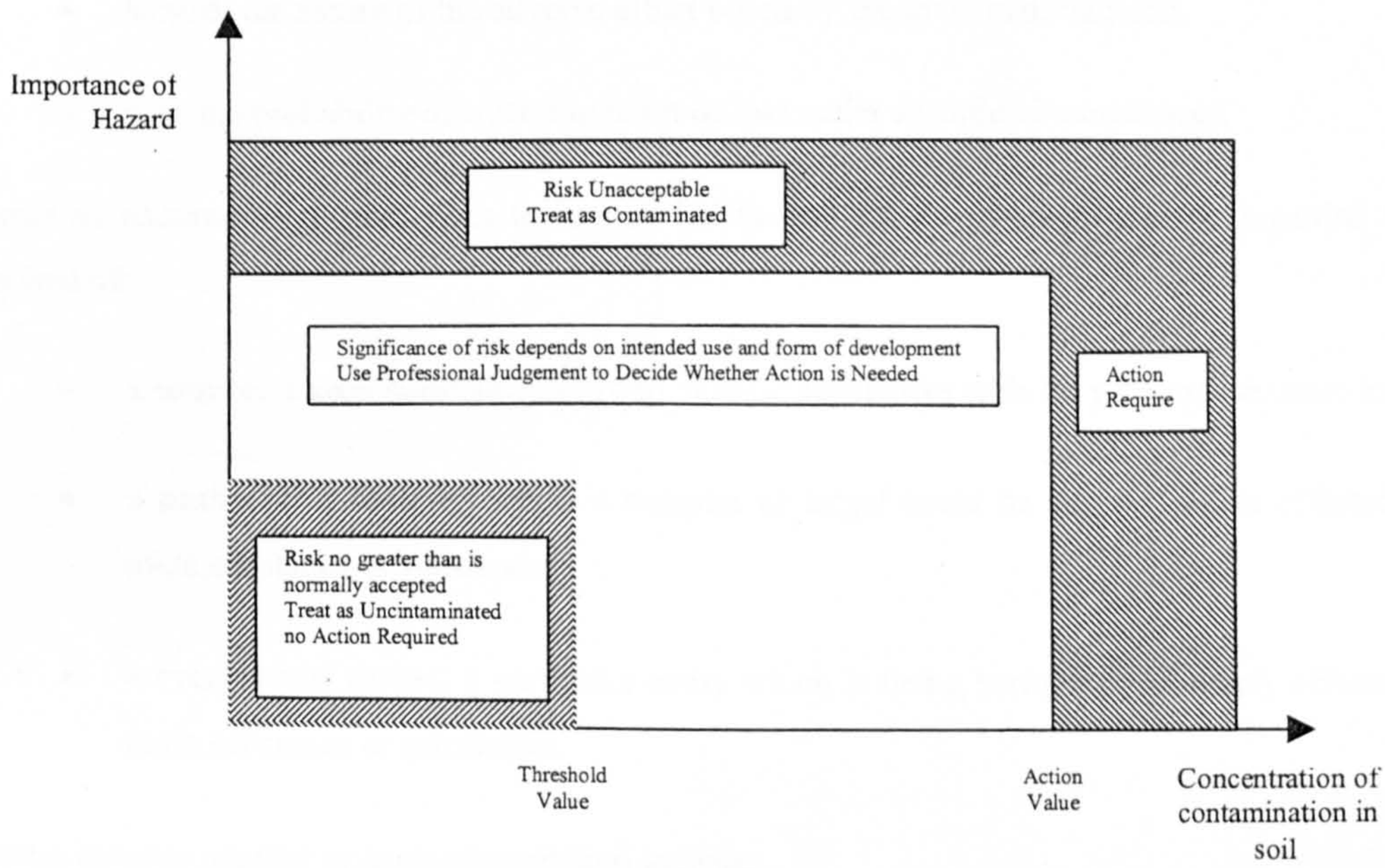

Figure 2: Assessment of Site Investigation Data (After ICRCL 1983)

The hazards and risks referred to by the ICRCL require careful definition as the term "risk" has a multitude of uses and should not be confused with "hazard". In the context of contaminated land, the term "risk" is used widely across disciplines when referring to issues such as first and third party liabilities, risks to human health and the environment, the perceived consequences of chemical exposure and the operational risk of project over-run. There is always a requirement, therefore, to state clearly what form of risk is under consideration and what its components are.

Smith (1985) states that although there is a link between past land use and the nature of contamination that is likely to be found, contaminated land should also be viewed in terms of the problems arising from the presence of particular substances, rather that from previous use. Thus, in the United Kingdom and elsewhere the nature of the problem of contaminated land is assessed in relation to specific sites and

depends upon many site specific factors and how they influence the degree of "risk" to a set of "targets" arising from the "hazards" presented by the contaminants that are present.

The ICRCL framework adopts this rationale and terminology that now forms an accepted international approach to the regulation of environmental media that embodies the fundamental distinctions between toxicity, hazard and risk. These terms are defined below (Young, P. J. *et al* 1997):

- toxicity: the potential of a material to produce injury in biological systems;
- hazard: the nature of the adverse effect posed by the toxic material; and,
- risk: the probability of suffering harm or loss under specific circumstances.

In terms of contaminated land, risks to human health and the environment can be regarded as being comprised of:

- **a source:** a toxic substance or group of toxic substances with the potential to cause harm;
- **a pathway:** a route by which a receptor or target could be exposed to, or effected by, the toxic substance or substances
- **a receptor or target:** a particular entity which is being harmed or adversely effected by the toxic substance or substances.

The main hazards relating to contaminated land include:

- flammable substances;
- explosives;
- asphyxiants;
- toxic substances;
- allergens;
- pathogens;
- carcinogens;
- mutagens;
- teratogen;

- sensitisers.

In the guideline documents, introduced above, the ICRCL identified a number of scenarios by which hazards arising from chemical exposure are characterised specifically by the nature of the adverse effect and the nature of the target they affect. These are (ICRCL 1987):

- domestic gardens and allotments;
- parks, playing fields and open spaces;
- any use where plants are to be grown; and
- buildings and hard cover.

In contrast to those hazards listed by Young, the ICRCL identify a more generalised group of "toxic" substances in addition to combustible substances and flammable gasses. However, they are more specific in relation to the hazards presented by asbestos, oily and tarry substances and hazards to construction materials.

The ICRCL system does not require the rigorous use of a "source-pathway-target" approach or the assessment of the probability of the hazard being realised in every situation. Instead the use of "trigger concentrations" provides a basis for the identification of hazards and guidance on the redevelopment of such sites using fixed "soil quality criteria" albeit in a flexible way that determines if further investigation is required. Therefore, where there is uncertainty relating to the nature of any risks involved whether this is due to the possible presence of hazards on the site or in relation to the potential use, the guidance (ICRCL 1987) advises that "professional judgement" be used "to decide whether action is needed". Consequently, this could ultimately require a full site risk assessment (Failey 1994). This could involve the identification of targets potentially at risk from contaminated sites which include (Smith 1985):

- Workers engaged in investigations, remedial or construction activities.
- Eventual residents (housing) or users (of schools, factories, recreational areas, etc) including potentially sensitive groups in the population such as small children.
- A wider population owing to pollution of aquifers and water courses, an wind blown pollution.
- Animals, plants, aquatic life, etc.
- Building structures, services and materials, e.g. by corrosion, fire or explosion.

- Investment if site closure or evacuation is required or if there is major damage to buildings.

Hazard/exposure combinations include the following:

A.	Physical hazards	(a)	explosion and fire
		(b)	subsidence
		(c)	corrosion of structures
		(d)	effects on mechanical properties of soil
B.	Toxic hazards		
	i. by inhalation	(a)	dust
		(b)	toxic gases
		(c)	asphyxiant gases
	ii. by ingestion	(a)	from fingers, etc (particularly children
		(b)	contamination of food
	iii. by direct ingestion	(a)	uptake of toxicants by edible plants
		(b)	contamination of water
	iv. by contact	(a)	skin irritation, etc
		(b)	absorption through skin
		(c)	retardation or death of plants, etc

The hazards can be further categorised as short term, for example those hazards posed to workers from explosion or acute toxic effect, or long term, for example the chronic effect of exposure to carcinogens or toxic metals that may be taken up in home grown fruit and vegetables.

2.4.3 CIRIA Guidance on Derelict Land

In the CIRIA Special Publication on building on derelict land, Leach & Goodger (1991) provide guidance on the investigation, appraisal, remedial treatment and building on sites which have become derelict. The report discusses the hazards associated with sites which have been filled or contaminated by industrial activity and provides guidance on the initial assessment, detailed site investigation, sampling techniques and final appraisal of derelict sites. The report describes a phased investigation strategy, that it recommends should conform to DD175 (BSI 1988) and BS5930 (BSI 1981). Phase 1, the initial investigation, comprising a desk study and site reconnaissance and phase 2, the detailed site investigation, a

detailed analytical study intended to provide quantitative information on hazards, with the objective of a full site appraisal. The guidance recognises that in practice, the data collected should be used to direct further investigations to specific areas. A preliminary investigation being followed by closer investigation of specific areas. The site appraisal is concerned with determining the technical and economic suitability of a site for a specific end use and provides a number of options for action with the intention of reducing the risks associated with any hazards discovered on the site. The options relate to not only remedial treatment in the latter stages of a development but also during the planning stages where options include the abandonment of a project, a change in the end use or a change of layout. This advice conforms with ICRCL guidance that developments should fit the site.

The way in which the CIRIA report deals with the remedial treatment of contaminated sites illustrates the lack of use of techniques for the treatment of contaminated land in the United Kingdom. The techniques espoused are civil engineering based methods. These techniques, described in the report as the "two methods which are currently in vogue for the treatment of contaminated sites", comprise the following methods:

- Reduce accessibility of contaminant under designed cover layer, and/or sometimes within barrier walls.
- Excavate the contaminated ground, remove to an approved tip and replace with clean material.

The report also makes it clear that although the use of techniques for the treatment of contaminated land was growing overseas, few were at the stage of practical application in the United Kingdom. However, the report does illustrate the early development of the *suitable for use* process in the advice given on site use. Furthermore, it deals with the development of derelict sites rather than contaminated land, the definition of which is now associated with the more seriously contaminated sites due recent legal definitions of contamination.

2.4.4 The Application of ICRCL Guidance and the use of Treatment Technologies

An example of the way in which the ICRCL guidelines have been used in relation to the reclamation of contaminated sites is provided by the Beaumont Leys Sewage Farm in Leicester. At this site, sewage sludge was applied to parts of the surrounding agricultural land, however, this was later found to contain high levels of metal contaminants. Specifically, lead, cadmium, nickel, zinc and copper had been adsorbed by the soil. The discovery of these high levels of metal contamination led to the re-appraisal of the development plans for the area as originally the Local Authority had planned to build houses with private gardens on areas exhibiting significantly elevated cadmium and lead concentrations (Heeps, 1979). Because some plant species are able to tolerate elevated levels of absorbed contamination in their foliage and fruit, the development of the site for housing presented the possibility that such vegetation could be

consumed by humans or animals (Davis 1979). Consequently, the development that was also to comprise industrial and open recreational uses was altered, in line with the ICRCL guidance that development should fit the site (see below), to take account of this.

The above example illustrates the concept, espoused in ICRCL guidance, that some uses of a site are more sensitive to the presence of contamination than others. In general, a sensitive site use is one in which there may be prolonged and close contact with the soil, as could be the case with small children or where vegetables are grown for consumption in the home. The least sensitive use is that of concrete or tarmac hardstandings or where buildings cover the site and therefore restrict access to the soil.

ICRCL policy is concerned with promoting the beneficial use of contaminated sites. Local Authorities and other organisations involved with the remedial treatment are encouraged to adopt a systematic approach to the development of contaminated sites and are concerned with the management and containment of environmental liabilities and not necessarily with the remediation of contaminated soils to a pristine condition (Failey & Scrivens 1994). The ICRCL introduced a system where the careful assessment of information from a site investigation is used to decide whether a redevelopment proposal goes forward unmodified, whether remedial measures are required or whether an alternative use for the site would be more appropriate (Lord 1987). This involves answering the following questions in a systematic manner before deciding on the future use of a site (ICRCL 1987):

1. What is the history of the site?

2. What is the intended use of the site?

3. Which hazards are likely to affect that use?

4. Which contaminants give rise to those hazards?

5. Are there contaminants present, and if so in what concentrations and with what distribution?

6. Are there any hazards, and if so how might they be removed or reduced?

7. Could the hazards be more effectively removed or reduced by choosing a different land use?

8. What remedial treatment is practicable, and what monitoring is needed to enable the site to be used for the chosen purpose?

Harris (1987) makes the point that the ICRCL recommends that the redevelopment of contaminated land should actually dictate the end use of a site and not the end use the level of remedial action that is required. Indeed this is evident from the relative positioning of points 7 and 8. This type of approach seeks to reduce

reliance upon treatment techniques for the amelioration of contamination by making "the development fit the site", rather than "making the site fit for the development". Indeed it illustrates that the ICRCL were actively discouraging the use of treatment techniques in the advice they were giving. This advice appears to be unrealistic from the point of view of a private developer. However, when considered in the context of the original purpose of the ICRCL guidance, which was to provide guidance primarily to local authorities, it appears less unreasonable. This technique, which is referred to in recent CIRIA guidance on the remedial treatment of contaminated land as risk avoidance (Harris *et al* 1995b), is discussed further in Section 2.5.

2.4.5 The Environmental Protection Act (EPA) 1990

Prior to the promulgation of the EPA 1990, the United Kingdom's approach to contaminated land was based upon (ICRCL 1987):

- a free-market approach which places the responsibility for dealing with unacceptable contamination on the developer of land with no specific central commitment to deal with contamination which has already occurred;

- reliance on existing pollution control and environmental protection legislation to reduce or prevent contamination on sites in active use;

- reliance on the planning system to regulate decisions on land use; and

- provision of financial incentives for re-use of land in urban areas, directing resources primarily to after-uses consistent with other objectives.

However, although there was no specific regulation related to contaminated land in the United Kingdom prior to the promulgation of the Environmental Protection Act in 1991, it is evident from the section above that the UK was among the first advanced industrialised nations to realise that the legacy of industrial development had implications beyond those of simple physical dereliction. Indeed bodies such as the ICRCL and CIRIA had been involved in the production of guidance for some time before the proposals for the Environmental Protection Act 1990 were issued, and a substantial body of practical experience in redeveloping contaminated land already existed (Harris & Denner 1997).

The House of Commons Environment Committee, under the chairmanship of Sir Hugh Rossi, criticised this policy as reactive and concluded that the United Kingdom may be underestimating a genuine environmental problem and misdirecting effort and resources. Their first report made 29 separate recommendations for consideration by the government. Some called for the introduction of specific legislation, other for the reorganisation of departmental responsibilities for policy development and the

provision of guidance. Many highlighted the general need for a more comprehensive policy approach. The main criticisms were (House of Commons Environment Committee 1990)[6]:

- The narrow working definition of contaminated land which referred only to that land which is contaminated and "potentially available for development", thus apparently excluding other potential categories of contaminated land, including land already in use and land affected by the migration of contaminants.

- The lack of reliable information on the scale, nature and distribution of contaminated land in the United Kingdom.

- The failure to encourage active consideration of the wider environmental protection and pollution control aspects of land contamination because of the prominence given to redevelopment, although the Committee broadly endorsed the United Kingdom approach of taking the proposed end-use into account when redeveloping contaminated land.

- Limitation in the available technical guidance, particularly in relation to the water environment and the range of contaminants covered.

- The failure to encourage the use of a broad range of remedial techniques, other than conventional containment and off-site disposal, through research and development, improved technical guidance and better targeted grant assistance.

In its response to the Committee's report, the Government did not agree with all the conclusions drawn by the Committee, nor did it accept that action was required in response to all the Committee's recommendations. However, it was conceded that more could be done to improve the availability of information on the nature and scale of contaminated land, on assessment and in relation to research and development (Harris & Denner 1997). Attempts to address these deficiencies have experienced different degrees of success. The Section 143 registers were an attempt to improve knowledge relating to the nature and extent of contaminated land in the United Kingdom. Their failed introduction, the resultant policy review and the development of the *suitable for use* policy is discussed below. In relation to information on research and development into treatment techniques and the assessment of contaminated land a number of important studies have been published relatively recently that go some way to addressing these needs. For example, CIRIA have published a twelve volume series of special publications on the remedial treatment for contaminated land (Harris *et al* 1995a-e) and Martin & Bardos (1996) have published a comprehensive

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[6] House of Commons Environment Committee. Session 1989-1990. First Report: Contaminated Land. HMSO. p170.

review of full scale treatment technologies for the remediation of contaminated land. These publications are discussed in more detail in Section 2.5 and in Appendix 6.

The introduction of the Environmental Protection Act 1990 introduced, for the first time in the United Kingdom, legislation with specific implications for the management of contaminated land. The development of these policies are described below.

The Section 143 Registers

The development of a register of contaminated sites was considered a prerequisite for the introduction of contaminated land policies in industrialised countries (Cairney 1993)(House of Commons Environment Committee 1990). However, such registers commonly produced daunting results. The Dutch inventory had revealed 110,000 sites and the German 100,000. It was therefore expected that the British inventory- to be introduced by Section 143 of the Environmental Protection Act 1990[7]- would reveal between 50,000 and 100,000 sites (Ends 1991c).

One of the main purposes of the Section 143 Registers was to provide information for land transactions. The DoE envisaged the Law Commission recommending that solicitors be required to search the register as a standard part of conveyance procedure and that the buyer would be protected through the Misrepresentations Act 1967 if information was withheld (Ends 1991b).

However, the DoE greatly underestimated the response the Section 143 Registers would receive. Industry and lenders contended they would cause land blight. In addition, it was claimed that there would be a public outcry over the potential of contamination to cause harm that would result in a need for extensive site investigations and remedial treatment. Such investigations and treatment would be the responsibility of the land owners and not the original polluters (Ends 1992a).

In an attempt to address these criticisms the DoE announced measures for raising funds from the private sector to pay for the investigation and clean-up of contaminated land- though it was clear on evidence from other countries that only 5% to 10% of these costs could be met by the Government (Ends 1991d). After considering, and rejecting, a Superfund style concept of strict liability and a levy on industry (Ends 1992c)- the Government delayed the regulations and then published a much watered down version (Ends 1992b). In March 1993 the Section 143 Registers were finally abolished due to strong opposition by property developers, chartered surveyors, insurers, bankers and many sections of industry (Ends 1993a).

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[7] The public registers of land which may be contaminated, which were to be introduced by Section 143 of the Environmental Protection Act 1990, are also commonly refered to as the "Section 143 Registers" or the "contaminated land registers"

Suitable for Use

Cairney (1993) considers liability for retrospective contamination to have been the main stumbling block in the contaminated land regimes adopted in industrialised countries. The failure of the Section 143 Registers as a result of industrial lobbying provides an illustration of this phenomena and also prompted a review of the United Kingdom's contaminated land policy (Ends 1993a). This review resulted in the publication of the consultation document "Paying for our Past" (DoE 1994b), a document that received criticism for its lack of innovation and decision (Forster 1994; Rossi 1995), and ultimately "Framework for Contaminated Land" (DoE 1994a) or "Framework". In this, the conclusion to the earlier consultation document, the DoE proposed that the United Kingdom's existing legislative framework can be applied to the problem of contaminated land. It outlined the concept of *suitable for use* that relies on the planning system to bring contaminated land, or brownfield sites, back into use when they come up for redevelopment. *Suitable for use* requires remedial activity only to the extent that sites are fit for their intended purpose.

Under this system, local planning authorities are required to draw up strategic development plans that are to be used to aid plan-led, as opposed to development-led, planning. Just as the ICRCL guidelines were only voluntary, *suitable for use*, as discussed in draft guidance issued to local authorities on the definition of contaminated land, requires that the levels of any remedial action be based on "the fundamental principles of risk assessment" (DoE 1995).

The Framework states:

> "This approach requires remedial action only where:
>
> - the contamination poses unacceptable actual or potential risks to human health or the environment; and
>
> - there are appropriate and cost-effective means available to do so, taking into account the actual or intended use of the site"

In relation to the remediation of land that poses a threat to human health or the environment Section 57 of the Environment Act 1995 introduces the following definition after Section 78 of the Environmental Protection Act 1990:

> "Contaminated land" is 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.

Uncertainty still exists as to precisely what this definition means as the guidance that instructs local authorities how to decide is still undergoing consultation. This guidance is important as Section 57 of the Act is only a framework. Until the guidance is issued, local authorities will not be in a position to assess whether there is contamination, as defined by the Act, in their areas. It is now apparent that the final version of the guidance will not be published until the Spring of 1999 due to a public spending review announced by the incoming Labour Government (Ends 1997b). However, when the guidance is published this still does not imply that local authorities will actually carry out any surveys of contamination or issue any remediation notices. Undoubtedly, the level of activity will vary depending on the diligence of the authority in question. Some will know where contamination exists as a result of the aborted Section 143 Registers, others will have to start from scratch (Wills 1996).

2.4.6 Guidance from CIRIA and the DoE

Despite the delays in the promulgation of the guidance relating to Section 57 of the Environment Act, research by the ICE, CIRIA and the DoE has continued and has resulted in the publication of a number of publications of use to professionals working in the contaminated land field.

CIRIA has published a twelve volume series entitled "Remedial Treatment of Contaminated Land" with the aim of assisting those involved in remediating contaminated land with the selection and implementation of effective, economic and safe solutions- an objective in keeping with the *suitable for use* philosophy. Consequently, the reports pay particular attention to the risk management approach, which is detailed in Volume III of the series (Harris *et al* 1995a), in the report on site investigation and assessment.

Interestingly, Volume III makes no reference to the use of ICRCL guidance on the investigation and assessment of contaminated land even though, and possibly because, it is readily apparent that the volume covers much the same area- albeit in considerably greater depth.

The risk management approach can be considered an evolution of the approach developed by the ICRCL guidance and has the purpose of providing an "objective, iterative process for identifying, describing and evaluating the risks that may be associated with contaminated land and deciding the best way of controlling or reducing these risks, and implementing strategies to achieve acceptable levels of risk". In so doing the report adopts a wider definition of contaminated than that used in Section 57 of the Environment Act based upon the presence in the environment of an alien substance or agent, or energy, with the potential to cause harm. The requirement that there be a significant possibility of significant harm, the test introduced by Section 57, is clearly a more stringent interpretation of contamination.

Risk management is defined in the report as:

> "the process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probabilities of occurrence"

And which involves:

- Hazard identification
- Hazard assessment
- Risk estimation
- Risk evaluation
- Risk control

This approach is a reiteration of the ICRCL approach but where the CIRIA guidance departs from the ICRCL approach is that it provides more comprehensive guidance of the application of such an approach and in so doing it draws from a number of sources- some of which the report acknowledges originate from outside the United Kingdom.

The report describes a site investigation approach including: the planning of an investigation; its implementation; the development and application of sampling strategies that enables the collection of data and in order to enable or identify:

- Hazards on a site-specific basis and their magnitude.
- The types and degree of the hazards and any potential exposure pathways.
- The likelihood of any adverse effects and the magnitude of the harm.
- The significance of the risks.
- A decision to be made on the best way to reduce or control any risks.

The report makes it clear that the investigation and remedial treatment of contaminated land is an iterative process and that several phases of investigation may be required to enable hazards to be characterized, pathways to be identified and estimates of the risks involved to be made. In addition, it is also apparent that supplementary investigations may be necessary throughout the redevelopment process to reassess risks and supplement the remediation process.

2.5 CLASSIFICATION AND SELECTION OF REMEDIAL METHODS

Volume IV of the CIRIA report on the remedial treatment of contaminated land covers the classification and selection of remedial methods (Harris *et al* 1995b). However, in order to do this it is acknowledged in the report that there is a lack of experience with the use of treatment techniques in the United Kingdom and consequently, the report draws heavily from work conducted in the United States for the USEPA.

Volume IV states that when, based upon the identification of hazards and the establishment of a source/pathway/target relationship, contaminants on site present an unacceptable risk to human health, building materials or the wider environment, they can be controlled or reduced to an appropriate level by the use of risk reduction or risk avoidance techniques. In addition the report states that it is at the point when assessment shows action is needed that the selection process begins- a process which is concerned with deciding:

- Which of the available remedial measures is best able, in whole or in part, to meet the objectives set by the risk assessment; and,

- How these methods, if necessary, can be usefully combined to produce an effective remedial strategy for a site as a whole, given site-specific circumstances including funding levels and programming constraints.

Where contaminants on a site present unacceptable risks, they can be controlled or reduced to an appropriate level by risk avoidance or risk reduction measures. These options are discussed below.

Risk Avoidance

Risk avoidance measures attempt to prevent contact between contaminants and targets through the adoption of an alternative site use or a modification of the site layout. This can provide an effective and pragmatic solution and offer a means of managing resources. Such techniques are not applicable where: the presence of untreated contaminants could continue to threaten human health, the water environment or other vulnerable targets; or, the use and layout of the of the site are fixed and to change this would be prohibitively expensive. Furthermore, it should also be noted that risk avoidance measured do not improve the condition of the ground. Thus, further investigations, assessment, monitoring and possibly treatment will have to be considered if site conditions change or if a new use is proposed. A cost-benefit analysis can be used to decide if a risk avoidance strategy could be pursued. If such a method is pursued than it is essential that full records of these decisions are kept and made available to subsequent users.

Risk Reduction

Risk reduction measures involve the removal, control or modification of contamination sources or migration pathways. This can be accomplished through the use of either civil engineering based methods or through the use of treatment techniques.

The options available to reduce the risks involved with contaminated land are summarised below. Both civil engineering techniques and treatment techniques are described and their relative advantages and disadvantages are given.

Information on the capabilities and limitations of individual civil engineering or process based treatment techniques are included in Appendix 6. This information is summarised below. The summaries are based upon the CIRIA special publications on the remedial treatment of contaminated land and specifically the following volumes and with further reference to Martin & Bardos (1996) and Wood (1997).

- Vol III. Site Investigation and Assessment. (Harris *et al* 1995a)
- Vol IV. Classification and Selection of Remedial Measures. (Harris *et al* 1995b)
- Vol VII. Ex-Situ Remedial Methods for Soils, Sludges and Sediments. (Harris *et al* 1995c)
- Vol VIII. Ex-Situ Remedial Methods for Contaminated Groundwater and Other Liquids. (Harris *et al* 1995d)
- Vol IX. In-Situ Methods of Remediation. (Harris *et al* 1995e)

Martin & Bardos conducted an extensive review of treatment techniques for the remedial treatment of contaminated land under contract to the Royal Commission on Environmental Pollution. The report reviews "established treatment technologies" which it defines as "those with which commercial full scale site remediation has been carried out or is being carried out at several sites". This definition is similar to the definition of treatment techniques use by this thesis although it does not include reference to remedial techniques in the early stages of development. The review covers treatment processes considered "established" in the United Kingdom, North America and Europe, it also reviews 43 case studies (of which 7 are from the United Kingdom). Wood also provides a review of treatment techniques, which also draws heavily from the CIRIA and Martin & Bardos work, but also includes indicative prices for in-situ and ex-situ treatment techniques.

2.5.2 Classification of Remedial Methods

Civil Engineering Based Methods

Civil engineering based methods can be classified into three main groups (Harris and Herbert 1994):

- The excavation and removal of contaminated material
- The physical containment of contaminated material using cover systems or in-ground barriers
- Hydraulic controls, used in conjunction with the above

In general, civil engineering based methods are comparatively insensitive to variations in the concentrations and types of contaminants present, or the types of contaminated material being handled. Consequently, they have a wide applicability. In addition, these techniques are well established, are familiar to both designers and contractors and use widely available plant, materials and equipment. However, these techniques do suffer from a number of limitations which include:

- the process of excavation can cause environmental or health impacts;
- containment systems do not materially reduce the volume or the hazardous properties of contaminated material;
- the systems have a finite life time; and
- the effectiveness of these systems are thought to decrease over time.

Process Based Treatment Techniques

Techniques for the remedial treatment of contaminated land can be loosely grouped into the categories listed in Table 5. This classification is that used by the Warren Springs Laboratory[8].

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[8] The Warren Springs Laboratory was a research establishment (it is now a part of AEA Technology) that carried out research work for the DoE and the NATO/CCMS pilot study on contaminated land. Much of the work relating to the development of advanced techniques for the remedial treatment of contaminated land in the United Kingdom was undertaken at the Warren Springs Laboratory, and much of it by Dr Paul Bardos (Bardos 1991; Bardos 1994a; Wood and Bardos 1994; Martin & Bardos 1996).

Table 5: Categories of Remedial Technique (After Crowcroft et al. 1992)

Biological treatment techniques dependent upon the biological transformation or mineralisation of contaminants.
Chemical (including stabilisation techniques) treatment techniques used to destroy, fix or neutralise contaminants.
Physical treatment techniques used to remove contaminants from the soil matrix and concentrate them for further processing or removal.
Solidification treatment techniques used to encapsulate contaminants in monolithic solids of high structural integrity.
Thermal treatment techniques based upon incineration, gasification or pyrolysis at elevated temperatures.

Compared to civil engineering methods, process based treatment techniques have much more specific capabilities and requirements. As a result they tend to be restricted to a more limited range of contaminants and media. However, many have the advantage of reducing the volume or concentration of hazardous substances within contaminated material and, if they also destroy the contaminants, can provide a more permanent solution (Harris and Herbert 1994).

Process based methods may be applied in-situ or ex-situ. Ex-situ refers to the processes applied to excavated soil either on or off-site. In-situ refers to processes occurring in unexcavated soil, which remains relatively undisturbed. In-situ applications avoid the cost and potential health, safety and environmental impacts associated with the excavation of contaminated materials. In practice ex-situ techniques tend to be used more widely as they allow greater control over the treatment process. In-situ techniques have a higher degree of uncertainty in relation to: the behaviour of the contaminants; the control of the treatment area; the effect on the surrounding area; and, the demonstration of the effectiveness of the treatment (Martin & Bardos 1996).

Work by the Warren Springs Laboratory has also summarised the technical problems specific to treatment techniques. These are summarised below (Armishaw *et al,* 1992).

- **Process specificity.** Remedial techniques are limited in their ability to treat a wide variety of contaminants.

- **Contaminant accessibility and availability.** Accessibility refers to a technique's ability to reach an area of contamination- a particular problem with in-situ processes and when dealing with fine grained

soils. Availability refers to the ease with which treatable contaminants are incorporated into the treatment process- this depends upon the contaminants solubility, volatility and sorption to soil components. Less available contaminants require longer treatment times and again are a disadvantage for many in-situ applications.

- **Residual contaminants.** Problems caused by accessibility and availability may result in the residual contamination of remediated soil. This is a particular problem for in-situ processes as access to all areas of contamination cannot be assured. Bioremediation techniques rarely remove greater than 90% of biodegradable contamination. This includes problems of **materials handling**, particularly in ex-situ processes during the excavation, treatment and return of soil.

- **Impact of treatments.** Remedial techniques can change the structure of soil. Soils treated by ex-situ processes, particularly thermal and solidification techniques, can often only be used as ballast or fill. Most remedial techniques disrupt soil fauna and microbial populations. In-situ processes can leave residual amendments such as surfactants, nutrients or unreacted chemicals.

- **Fouling of treatment systems.** Both in-situ and ex-situ treatment systems can experience fouling problems due to chemical precipitation or the growth of algae or fungi.

2.5.3 The Selection of Remedial Methods

Guidance on the selection of remedial methods has been provided by both the ICE (Harris and Herbert 1994) and CIRIA (Harris *et al* 1995b). However, it is apparent that both of the documents referenced above have the same author and can be seen to have a similar source with the latter providing the most comprehensive guidance.

The selection process described is intended to encourage an objective consideration of all issues relevant to the selection of remedial methods and to ensure that selection decisions are justified, documented and communicated to all relevant parties. The issues covered include the cost of remedial works, the practical difficulties of implementation (including programming constraints), the need to reconcile often conflicting objectives, and legal or community-based objections to the use of particular methods.

In order to accomplish these objectives, the selection process has two main stages which are:

1. the determination of remediation objectives and the identification of those remedial methods most likely to be applicable, effective and feasible; and,

2. the detailed appraisal of the remedial strategies and the selection of the preferred strategy based upon the best balance between technical effectiveness, practicality and cost.

These stages of the selection process illustrate the conflicts that exist in relation to contamination-remediation objectives and management objectives. Contamination related objectives are derived from the risk assessment process and have the purpose of obtaining a site with a low level of contamination-related risk. However, management objectives relate to the time and cost of conducting an investigation and consequently can constrain the range of technical options. Examples of management objectives include: the treatment of a site within a specific time or budget; the avoidance of long term legal liabilities; the ease with which a site can be sold or the acceptability to funding and insurance bodies.

The conflict between contamination-remediation and management objectives highlights the importance of being able to assess detailed information on abilities of treatment techniques. Both CIRIA and the ICE in their guidance emphasise the importance of obtaining information relating to the effectiveness, practicality and cost of treatment techniques, as this information is necessary in order to assess the ability of a technique to meet contamination and management objectives.

A more recent indication of the cost range for treatment techniques than that provided by Crowcroft (1992) in Table 4 is provided by Wood (1997) in Table 6. The range of prices for individual techniques can be seen to vary greatly both for specific techniques and particularly between the varieties of treatment technique. This is inevitable due to the diverse range of techniques available, as illustrated by the above account. However, it is also apparent that the cost of biological treatment techniques has reduced to a competitive level.

Table 6: Indicative Cost Range for Treatment Techniques (Wood 1997)

Physical Treatment Techniques	
Soil Washing	£50 - £250 per ton
Physico-chemical Treatment	£50 - £170 per ton
SVE	£10 - £90 per ton
Thermal Treatment Techniques	
Thermal Desorption	£40 - £700 per ton
Incineration	£50 - £1200 per ton
Solidifcation/Stabilisation Treatment Techniques	
Solidification: cement based	£20 - £170 per ton
Solidification: lime based	£20 - £40 per ton
Kiln-based vitrification	£30 - £500 per ton
Biological Treatment Techniques	
Biopiles	£15 - £45 per ton
Landfarming	£10 - £100 per ton
Windrow Turning	£5 - £60 per ton
Bioreactors	£50 - £80 per ton
In-situ Bioventing	£15 - £80 per ton
In-situ Bioremediation	£5 - £160 per ton
Chemical Treatment Technique	
Solvent extraction	£30 - £600 per ton
Soil flushing	£25 - £80 per ton

2.6 THE EVOLUTION AND DEVELOPMENT OF TREATMENT TECHNIQUES

2.6.1 RCRA, HSWA, CERCLA & SARA

Much of the work into the development of techniques for the remedial treatment of contaminated land has been carried out in the United States. This situation is acknowledged in the recent 12 volume CIRIA publication on the Remedial Treatment of Contaminated Land, which based much of its guidance concerning the classification and selection of treatment techniques on research carried out in the United States for the USEPA (Harris *et al* 1995a,b). The development of treatment techniques can be largely

attributed to the promulgation of RCRA[9], and it's reauthorisation HSWA[10]. The latter restricted the disposal of hazardous waste in landfill and required solutions that were the Best Demonstrable Available Technology (BDAT). The intention of these "landbans" was to make land disposal a last resort and to move hazardous waste management towards more "sustainable" technologies. In addition, the two Superfund Acts CERCLA and SARA created a massive remedial programme for the clean-up of sites that threatened the environment. Consequently, by the middle of the 1980s the United States had developed a regulation driven market for techniques for the treatment of contaminated land (Conner 1994; LaGrega et al. 1994).

The USEPA's Superfund programme was introduced in 1980 and was intended to be a relatively short-term project to clean-up abandoned hazardous waste sites. Since then, however, thousands of sites have been discovered and their clean-up has proved to be far more costly and complicated than anticipated. In addition to the problems of strict liability, described in Section 2.3, Superfund suffers from a variety of administrative problems. Two counterproductive themes are: a tendency toward over investment in remediation actions; and, a tendency toward costly litigation which often does nothing but delay clean-up (Blacker and Goodman 1994). In addition, Superfund groundwater clean-up standards require water to be remediated to drinking water levels- a goal only achieved at about 10% of sites, according to a National Research Council Study (MacDonald and Kavanaugh 1995). By 1994, when the Superfund programme expired, it was recognised that reform was required (Andrews 1995).

The United States General Accounting Office (GAO) suggested that (GAO 1995):

- risk should drive resource allocation;
- effort was needed for the USEPA to recover its costs; and
- contract management at Superfund sites was needed.

These measures are intended to increase the cost effectiveness of the Superfund programme. A further example of such an initiative is the Superfund Accelerated Clean-up Model (SACM) which is an attempt to remediate sites efficiently by reducing the regulatory and bureaucratic burden on RPs. This involves negotiation between regulators and developers at the early stage of a project in order to remove as much of

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[9] *The Resource Conservation and Recovery Act*, PL 94-580, 1976. (RCRA)

[10] *The Hazardous and Solid Waste Amendments*, PL 98-616, 1984. (HSWA)

the unnecessary bureaucracy as possible and therefore reduce project time and costs (Blacker and Goodman 1994).

A further recognition of Superfund's problems is illustrated by the creation of the USEPA Brownfields Action Agenda in early 1995. This introduces a new tier of less serious, and less regulated, contaminated land. Land that it is intended can be redeveloped by state regulators without reference to the protracted Superfund requirements.

2.6.2 Policy Maturity

In the development of it's environmental policy framework the British Government considered it important that the major pitfalls encountered by other regulatory regimes be avoided (Wills 1996). Superfund has experienced a great many problems both in terms of the massive amount of litigation it has spawned but also to the extent that it has largely failed in the most important task of actually remediating contaminated land. Of the original 1320 Superfund sites designated for clean-up fewer than 300 have seen remedial action (Anon 1995a; GAO 1995). In the Netherlands the multi-functionality approach, that requires sites to be cleaned to a level that they be suitable for agricultural use, is also being backed away from for reasons of cost and the technical limitations of many remedial techniques. The DoE intends that *suitable for use* will fall into neither of these traps. By encouraging voluntary remediation the aim is to limit litigation and prevent issues of liability from reaching the courts (Jackson 1994).

An important question is will *suitable for use* or the Brownfields Action Agenda encourage those people who are potentially responsible for contaminated land to take action voluntarily or will regulators become, or continue to be, embroiled in protracted litigation when they attempt to force remedial action? Furthermore, if remediation is encouraged will it involve treatment techniques or will the emphasis be towards civil engineering methods in the majority of cases (Wills and Jones 1996a)?

2.6.3 The United States

Although Superfund was introduced in 1980, comparatively few sites had been cleaned up by 1986. In addition, regulators applied limited and inadequate technologies to complex problems. The restrictive nature of CERCLA clean-up standards eliminated the use of many low cost methods. By the mid 1980s it was clear that innovative treatment technologies were not being developed and that the existing technology was often inadequate and costly. Indeed, in 1988 the average cost of conducting a Superfund clean-up was estimated at $0.5-1million per hectare. Discussions with vendors of remedial techniques, many of which were small businesses, revealed that a lack of credibility was a fundamental problem. USEPA, state and private Superfund decision makers were unwilling to select untried technologies (Dowd 1988).

The techniques prescribed by the USEPA in the clean-up of such sites were predominantly on-site process plants, although, bioremediation and pump and treat systems were also in use at this time for organic contaminants. Table 7 lists the Records of Decision[11] for waste site remediation in FY1988 (Daley 1989 ; Lindsey and Kelly 1994).

However, in 1986 a number of factors did combine to stimulate the use and development of treatment techniques (Hirschhorn 1987):

- Superfund's reauthorisation;
- the requirement that hazardous waste be treated rather than encapsulated;
- an additional $8.5billion of funding; and
- the introduction of the Superfund Innovative Technology Evaluation (SITE) programme.

Table 7: Remedial Technologies Prescribed by the USEPA for Waste Site Remediation in FY1988 (After Daley 1989)

Incineration/thermal destruction	22
Solid/stabilisation/neutralisation	18
Volatilisation/soil aeration	7
Soil washing/flushing	7
Biotreatment	6
Vacuum extraction	10
Other	9
Containment	32

[11] Records of Decision (RODs) are administrative documents detailing the selection of specific remedial technologies.

Under the SITE programme, innovative treatment technologies[12] are demonstrated at Superfund sites. The developers of the techniques pay for the design and construction of the remedial work and the USEPA evaluate the technology and prepare an evaluation report (USEPA 1995c). The SITE programme has been successful in encouraging the use of innovative treatment technologies.

Figure *3* illustrates how the use of established and innovative techniques increased over containment after 1986.

Some of the innovative techniques developed at SITE demonstrations have, or are beginning, to become established in the market place. Such techniques include: soil vapour extraction, bioremediation and various forms of thermal desorption. Table 8 list the years in which a variety of treatment technologies were first used (USEPA 1995b).

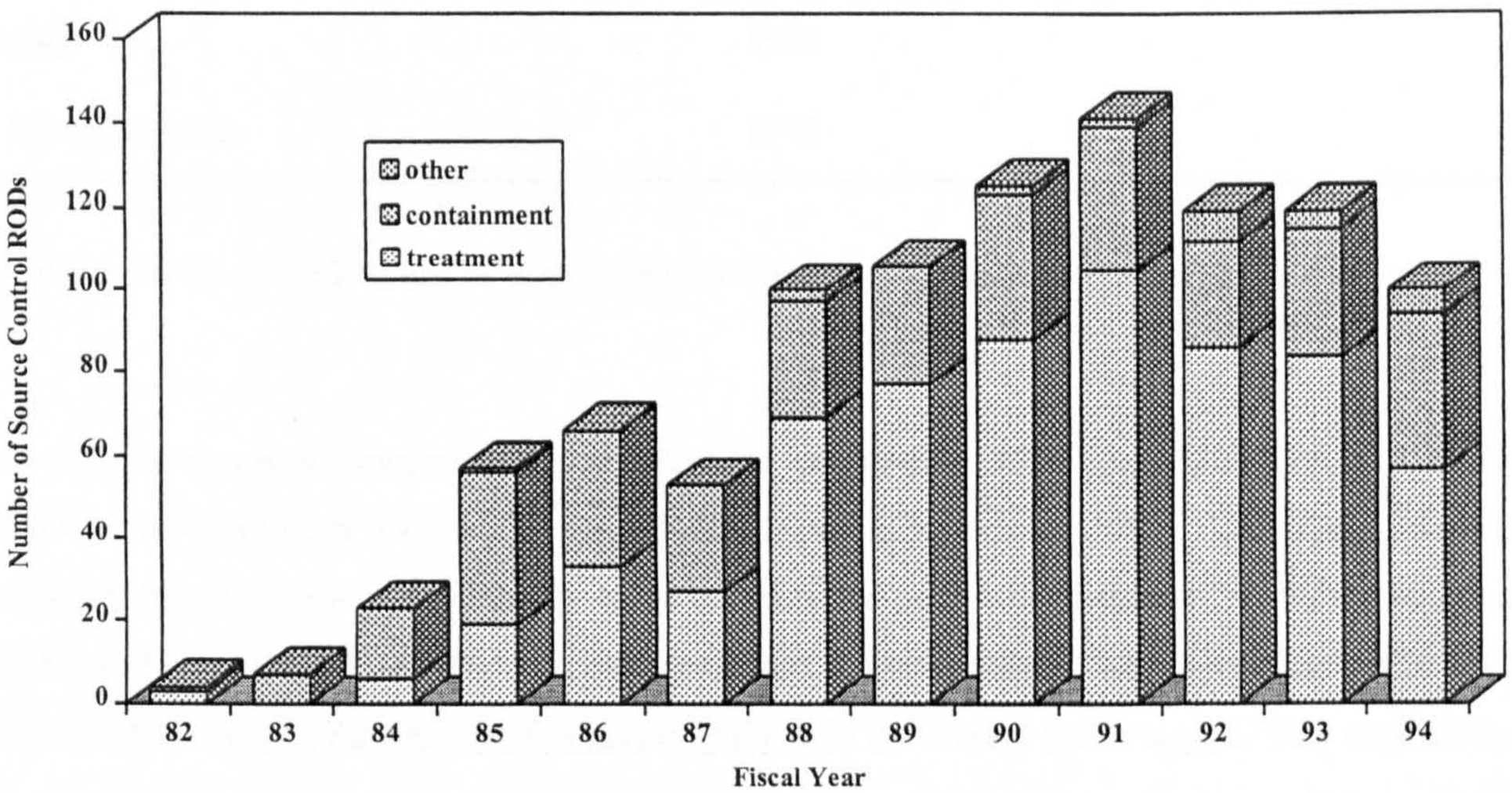

Figure 3: Superfund RODs by Fiscal Year (After USEPA 1995)

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[12] In relation to the level of development of a technique for the treatment of contaminated land as defined by this thesis, the definition of **innovative remedial techniques** used by the United States Environmental Protection Agency (USEPA) Technology Innovation Office (TIO) for innovative treatment technologies is:

"[Innovative remedial techniques] are alternative treatment technologies for which routine use is inhibited by lack of data on performance and cost. In general, a techniques is considered innovative if it has had limited full-scale application." (USEPA 1995b)

Table 8: Initial Use of Treatment Technologies at Superfund Sites (After USEPA 1995)

Technique	Year of first use
Solidification/stabilisation	1982
Bioremediation (ex situ)	1984
Off site incineration	1984
Soil vapour extraction	1985
On site incineration	1985
Bioremediation (in situ)	1987
Air sparging	1989
Passive treatment wells	1992

Figure 4 illustrates the increased use of both established and innovative remedial techniques at Superfund sites.

Estimates of the total cost of cleaning up all the NPL sites vary greatly. $32million, $80billion, $100billion and $500billion have all been quoted (Overcash 1987; Travis and Blaylock 1992). Although, as Section 2.3.2 described, much of this cost is thought to be the result of poor administration and the problems of strict liability and CAC regulation. However, these problems notwithstanding, the financial cost of both the established and innovative treatment technologies developed in the United States is high. This expense has both it's supporters- who argue that innovation can be exported to international markets- and it's detractors- who argue that the opportunity cost of Superfund is too great (Alm 1991; Dowd 1988).

Established remedial techniques are defined as those for which full scale site remediation and verification has been carried out on several sites.

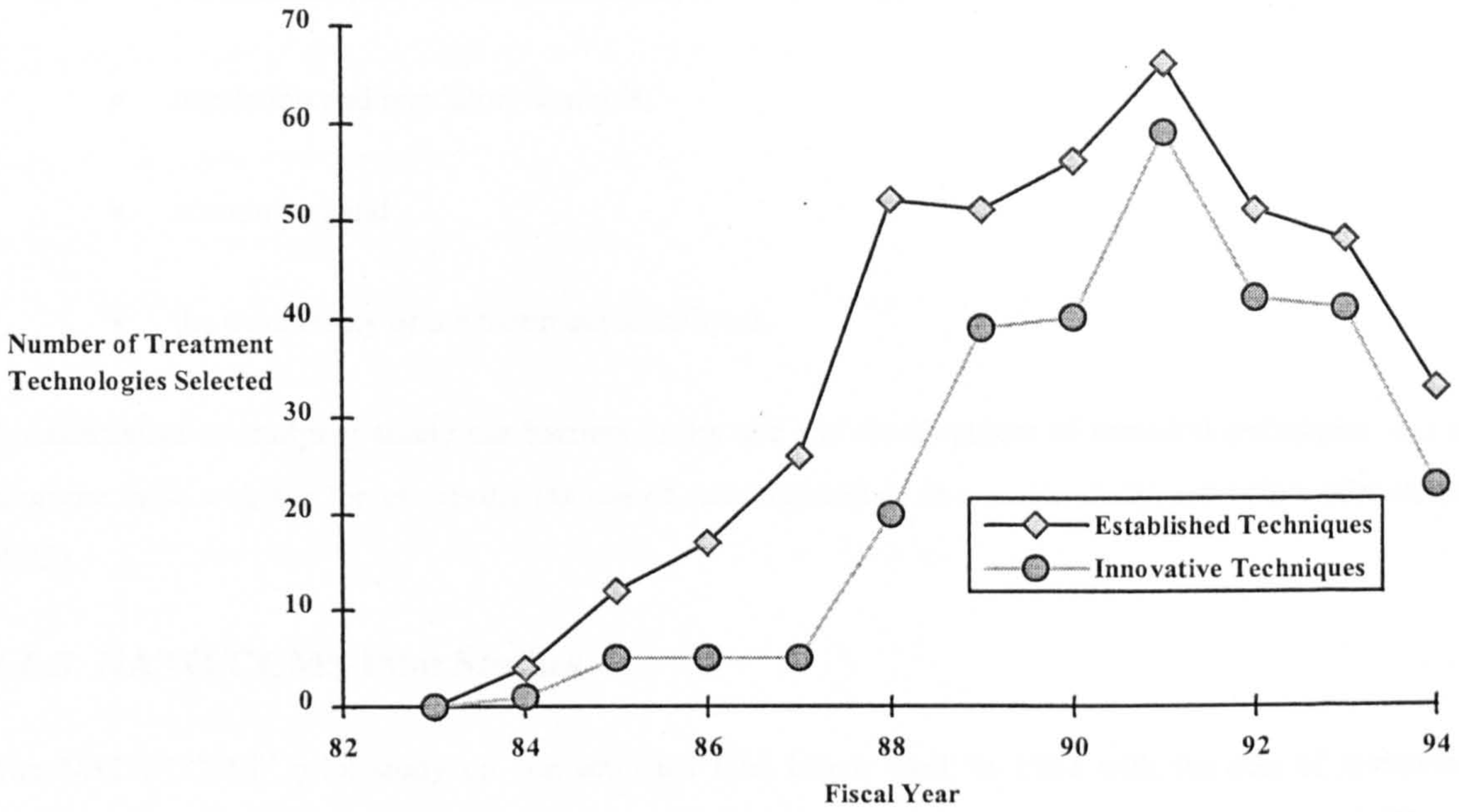

Figure 4: Superfund Remedial Actions- Number of Established Versus Innovative Treatment Technologies Selected (After USEPA 1995)

2.6.4 The United Kingdom

In comparison to the United States, the United Kingdom has been slow to develop a market for techniques for the treatment of contaminated land (Crowcroft 1992). The problems of contaminated land were recognised in the United Kingdom in the late 1970s. Concern stemmed from a gradual recognition of the problem, and the need to redevelop disused industrial land, rather than from a reaction to a specific event such as Love Canal (Harris 1987). However, despite opportunities for the application of remedial techniques and a growing understanding of their efficient use and development only a few process based treatment technologies had entered the United Kingdom's market by 1991 (Denner 1991).

It appeared that there were barriers to application and development of techniques for the treatment of contaminated land in the United Kingdom. The technical barriers to the use and development of treatment techniques have been described above. However, in addition to these it was recognised that the non technical barriers- institutional, financial, public concern and political decision making- were also considered areas of difficulty (Smith 1991). Wood and Bardos (1994) suggest: "the reasons for the limited use of process based technologies is because there are a number of constraints that act as impediments to their acceptance, use and commercialisation."; and categorises these impediments into four broad groupings:

- Performance, i.e. the technical ability of the techniques to treat contaminated soil but also;
- regulation and regulatory controls;
- economics; and
- the availability of the treatment techniques.

An alternative to studying solely the barriers to the use and development of remedial techniques was to combine these with the forces driving the use of such techniques in a single study, see below (Crowcroft 1992).

2.6.5 NATO/CCMS Pilot Studies

The NATO/CCMS[13] pilot study on contaminated land began work in 1981 with the aim of reviewing current knowledge of remedial measures particularly in relation to their long-term performance (Harris 1987). Now in its third term, the NATO/CCMS study has identified a number of ways in which the remedial treatment of contaminated land can be made more efficient. Suggestion have included:

- efficient site assessments- where the scale, nature and presence of interfering factors such as debris- are identified;
- clear process descriptions in technical literature;
- process integration; and
- the use of extensive treatment processes.

The last of these two were considered of particular importance.

Process integration

Process integration, an approach also referred to as a "treatment train", addresses the inability of simple unit processes to treat complex contaminated land problems by integrating a number of processes. Thus, complex contaminants can be addressed as individual fractions. Processes can be integrated by: separating contaminants ex-situ, e.g., combining soil washing with the use of chemical leachants to desorb

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[13] Committee on Challenges to Modern Society (CCMS).

contaminants; or, applying a number of techniques in-situ, e.g., the combination of soil vapour extraction and bioremediation to give bioventing (USEPA 1995b).

Extensive Treatment Processes

Traditional or intensive remedial techniques use sophisticated technologies and a lot of resources. Therefore, they tend to be costly. Extensive remedial techniques have low resource requirements but may take longer to operate. In addition to lower costs such techniques tend to have less impact on soil quality. Examples of extensive techniques include: biologically based treatments such as co-composting; cropping plants capable of accumulating heavy metal contaminants; and, the combination of engineering containment techniques with in-situ techniques such as biodegradation or pump and treat (Bardos 1991; Bardos 1994b).

2.6.6 Availability & Costs

Sections 2.2.1 and 2.2.2 discuss how markets for environmental goods and services require regulatory stimulation if they are to develop. The Superfund programme did this through the requirement that hazardous waste be treated rather than landfilled. However, no such requirement has existed in the United Kingdom. This approach has been criticised as short sighted and it has been suggested that a change in the attitude towards soil as a fundamental resource is required (House of Commons Environment Committee 1990; Smith 1991). Others, however, have suggested that such an approach cannot hope to restore contaminated land for all possible future uses and that the cost of such an approach would far outweigh the benefits gained (Denner 1991). Furthermore, even though remedial techniques are encouraged and used in the United States, landfill and incineration still remain the most important means of dealing with excavated soil. In addition, engineering solutions such as isolation, monitoring and control are amongst the most frequently used in-situ processes (Bardos 1994b).

Although the process of costing techniques for the treatment of contaminated land is difficult, Tables 4 and 6 illustrate two attempt to do this by Crowcroft (1992) and Wood (1997). However, the costs given must be viewed with caution, for the reason that treatment techniques are many and diverse in their nature and because site specific factors will inevitably cause variations in the performance of these techniques, they illustrate the disadvantage faced by techniques for the treatment of contaminated land when compared with the relatively unrestricted landfill market in the United Kingdom (Crowcroft 1992). However, they also illustrate a reduction in the cost of biological treatment techniques in recent years and consequently indicate an area where treatment techniques have the possibility to succeed.

2.6.7 Driving Forces & Barriers to Clean-up

Crowcroft (1992) identified a number of factors that influence the use of techniques for the treatment of contaminated land in the United Kingdom and some that are both barriers and driving forces. This study identified the possibility of the retention of contamination on site as a major factor preventing the use and acceptance of treatment techniques, but also of fundamental influence are cost constraints and a lack of confidence in their use (Crowcroft 1992). Table 9 summarises those issues that influence the development of techniques for the treatment of contaminated land and describes how they are of influence as both driving forces and barriers.

Table 9: Driving Forces and Barriers to the Uptake of Treatment techniques in the United Kingdom (After Crowcroft et al. 1992)

Issue	Driving Force	Barrier
National policy	Seeks to protect ground and surface water from contamination. Favours "destruction" of contamination.	Allows retention of contaminants on site. Accepts landfill as valid means of disposal of contamination.
Economics/grant availability	Derelict Land Grant (DLG) favours innovative technology.	Innovative technologies are more expensive than landfill/capping generally. DLG only makes up a proportion of reclamation cost and value.
UK Legislation	EA have power to enforce clean-up. Planning authority can require remedial measures.	UK policy is generally advisory rather than statutory. Planning regulations are not backed by a national policy.
EU Legislation	Forthcoming EU Directives likely to tighten controls and raise standards. Existing EU Directives form the basis of UK regulations on ground and surface water protection.	
Effectiveness	Some technologies may provide the only solution to a problem. In-situ techniques can cope with a developed site with least problems.	Complex sites may require more than one technology. Ex-situ techniques may prove too disruptive at some sites.
Standards	Drinking water standards will require more widespread use of new technology.	Allow the retention of contaminated soil beneath clean capping layers. Limited range of contaminants identified.
Public Awareness	Will perceive new technology as a permanent solution, not a transferral or burial of a problem. May boycott companies perceived as polluters.	NIMBY attitude to processing facilities.
Boardroom/ shareholder fund awareness	Concern for long-term security of investment. Concern for public image of company holding contaminated land.	Demand for minimum cost solutions.
Fear of being first		The desire not to be first to try a new process.
Availability	Some techniques readily available and marketed widely.	Some technologies only available from overseas base, i.e., high mobilisation costs.

2.7 SUMMARY & RESEARCH QUESTIONS

The aim of this thesis is to investigate the dynamics of the evolution and development of techniques for the remedial treatment of contaminated land. The aim of this chapter has been to identify the influences upon these factors in detail and to facilitate the identification of specific research issues to be explored.

Economists have demonstrated that contaminated land is caused by the failure of the market to incorporate external costs into the value of land. However, Coase (1960) has also demonstrated that the problem appears to be one of managing change through the market rather than recognising that externalities are not being taken into account. Therefore, the issue to be addressed by policy makers in terms of contaminated land, if this is indeed what the public desires, is one of manipulating the market in such a way as to efficiently bring about the changes in industrial practice an environmentally benign policy must entail. A way of addressing this situation could be to alter the market in such a way as to stimulate the use of remedial techniques. However, the problems of "command and control" regulation and strict liability are well documented. Furthermore, whilst environmental incentives are considered by many economists to be the logical solution to these problems, the issue of regulatory capture occurs when their introduction is attempted. In addition, if policy is to stimulated the development of treatment techniques- Government has an important role to play in the allocation of resources within an economic framework by the stimulation of "compliance innovation", i.e., the promulgation of laws and policy instruments that encourage or require the use, and therefore the development, of techniques for the remedial treatment of contaminated land.

Question: What are the influences of policy instruments designed to address the problem of contaminated land?

The problem of contaminated land had already been recognised in North America by the mid 1970s. This is illustrated by the work carried out on the redevelopment of contaminated land and reported at conferences such as that organised by the ASCE on "The Geotechnical Practice for Waste Disposal" held in June 1977. However, although the problems of contaminated land had been recognised, the regulatory regimes introduced in the United States and the Netherlands to deal with contaminated land were significantly influenced by the inflammation of public opinion as a result of high profile incidents at the Love Canal and Lekkerkerk. After these incidents, policy makers introduced Draconian legislation that was strict, retroactive, joint and several. Furthermore, the regimes were based upon CAC forms of regulation, that resulted in inflexibility, and excessively stringent clean-up standards that were difficult for techniques for the treatment of contaminated land to meet. In contrast, incidents such as that at Loscoe in Derbyshire and the Glory Hole in Portsmouth created considerably less public outcry.

A further effect of public opinion is the NIMBY attitude which can prevent the use of treatment techniques and civil engineering based methods alike.

Question: What is the influence of public opinion on the use and development of techniques for the treatment of contaminated land?

The British Government has attempted the introduction of "ecologically modern" policies that introduce iterative standards and attempt to harness transparent administrative practices and public opinion to promote the effectiveness of the policy. However, examples of such policies such as the Section 143 Registers failed at the hands of powerful lobbying on behalf of property developers and land owners because neither industry nor Government was ultimately prepared to accept the potential for blight and liability it was anticipated would be the result if the Registers (of *potentially* contaminated land) had been made public. Similarly, the reauthorisation of Superfund in the United States was hindered due to pressure from industry to reduce the stringency of groundwater clean-up standards. In addition, measures such as *suitable for use* and the Brownfields Action Agenda are attempts to promote the voluntary clean-up of contaminated sites where prescriptive regulation and liability has proved to be a hindrance to redevelopment.

Question: What is the influence of awareness of contaminated land and contaminated land liability in the business community?

Authors including Crowcroft *et al* (1992), Wood and Bardos (1994) and Smith (1991) suggests that, in the United Kingdom, the use of remedial techniques has been restricted by:

- the acceptance of containment as a remedial measure;
- the effect this has on the competitiveness of techniques for the treatment of contaminated land; and,
- a reluctance to use untried technologies.

However, it is apparent from the reviews of the use of established and innovative treatment technologies conducted by the USEPA that techniques for the treatment of contaminated land have been in use in the United States, in conjunction with more traditional approaches, since the mid to late 1980s. This market for treatment techniques has been stimulated by regulation that restricts the landfilling of hazardous waste (the "land-bans") and efforts to demonstrate and validate of treatment techniques (the SITE Programme). Work by the NATO/CCMS pilot study suggests more efficient remedial techniques need to be developed if they are to succeed.

Question: What is the influence of measures designed to stimulate the use and development of techniques for the treatment of contaminated land?

Since the recognition of the problem of contaminated land in the mid 1970s, understanding of the nature of the problems involved has increased to the extent that there is a good level of understanding of (Harris *et al* 1995a):

- the origins and evolution of contaminated land;
- the main types of hazard which are likely to be encountered; and
- the principal potential impacts associated with contamination.

Research by organisations such as the ICRCL, BSI, ICE, DoE and CIRIA in the United Kingdom and the USEPA and GAO in the United States adds to this knowledge on a continuous basis and provides best practice with relation to the investigation and remediation of contaminated land.

Question: What is the influence of the level of scientific understanding of, and the technical ability to deal with, contaminated land?

3. METHODOLOGY

3.1 OVERVIEW

Chapter 2 identifies a number of significant research questions representative of the dynamics of the development of techniques for the remedial treatment of contaminated land. Chapter 3 explains the methodology used to gather information to investigate them. An introduction to the methodology is provided in Section 1.5 of Chapter 1; this chapter aims to build on that introduction and to demonstrate that appropriate procedures were followed.

The justification for the methodology is presented in Section 3.2. This section begins with an explanation of why it was considered necessary to adopt the research design methodolgy proposed by Oppenheim (1992). This is followed in Section 3.2.2 by a description of the theoretical basis of this research. The methodology proper is discussed in Section 3.2.3 which includes an account of the research methodology that was finally selected and a critical assessment of the options that presented themselves after a review of the research design literature.

The research procedures are detailed in Section 3.3. Although the research was developed and conducted concurrently the procedures are detailed in three discrete sections: **Contacts and Briefings, Information Collection Techniques** and **Preparing the Information for Analysis.** The chapter is concluded by a summary in Section 3.4.

3.2 JUSTIFICATION FOR THE METHODOLOGY

3.2.1 The Need for a Research Design

It is clear from the preceding chapter and the review of treatment techniques provided in Appendix 6 that although technical issues have a considerable influence on the use and development of techniques for the treatment of contaminated land, the influences on their use are myriad and are influenced by factors other than of a technical nature. It is also apparent that many of the problems associated with the practical implementation of these techniques do not lend themselves to purely engineering based solutions and therefore their study by quantitative methods. This is because many of the influences on the development of treatment techniques depend upon factors such as value judgements, perceived risks, the potential for financial liability and future liability and economic considerations- decisions often made not by engineers but by lawyers, property developers, planners or investment fund managers, for example.

Furthermore, the research questions posed by the literature review did not seek to find mechanistic relationships but asked how intangible elements such as the law or public awareness influenced the development of treatment techniques. It was also recognised that to answer these questions information of a qualitative as opposed to a quantitative nature would be needed. Although there are precedents for the use of such approaches in relation to civil engineering, for example that of Jones (1991) which is discussed in Chapter 1 and Scott (1992) which is discussed below, it was recognised that the collection of such information is more commonly associated with the social sciences than geotechnical engineering. Consequently, in addition to a review of the work of Scott and Jones, a review of the methods of research design used by social scientists was undertaken.

The three main techniques used for primary data collection, i.e. data that cannot be collected from other sources, are listed by Rea & Parker (1992) as (a) survey research, (b) direct measurement, and (c) observation. They add that secondary research is the fourth means which consists of compiling and analysing data that have already been collected. Smith (1991) describes how survey methods have become the most used methods throughout the social sciences and he gives the following reasons in support of these methods:

1. The survey method is a good technique for the exploration of individuals' attitudes, values, beliefs and motives. It also allows retrieval of information about individuals' past histories.

2. Data collection is efficient as it can be structured in order to obtain specific information from a wide population.

3. The data is standardised in that respondents are assumed to react to the same stimuli.

4. As a form of data collection in social research, survey methods are comparatively cheap, simple and easy to administer.

A survey based methodology was considered most appropriate for this research. However, a cautious approach to the use of a social science based methodology was also taken due to the author's relative lack of experience with these methods. Consequently, before developing the methodology the process of research design was reviewed and the methodology developed by Oppenheim selected. The Oppenheim system of research design is a well respected and commonly used approach to the design of survey methods and was first developed by Dr A. N. Oppenheim of the London School of Economics in 1964 in his work "Questionnaire Design and Attitude Measurement". This approach to research design was augmented by that of Hakim (1987) which also relates specifically to the field of research design in the social sciences. Although Hakim's approach is considered to be a slight departure from the classical social science approach as developed by authors such as Oppenheim, it has been recommended as a thorough and

highly accessible by de Vaus (1996). Hakim defines research design as "the point at which questions raised in theoretical or policy debates are converted into operational research programmes which will provide answers to these questions". It is also emphasised that this process is of particular importance where multi-disciplinary research is being carried out and that the objectives of research design are to cut across theoretical and methodological divides between disciplines by designing the overall research design strategy in some detail at the "front end of a research design or project". Hakim asserts that design is the first and in many ways most significant step in developing research and that it is often not given significant attention.

The Oppenheim system of research design is outlined in Table 10. The system provides a general check-list for the selection of research methodologies. A number of steps are suggested with the intention of ensuring "precision, logic-tightness and efficient use of resources". Oppenheim (1992) states: "A poorly designed survey will fail to provide accurate answers to the questions under investigation; it will leave loopholes in the conclusions; it will permit little generalisation; and it will produce irrelevant information, thereby wasting case materials and resources".

Time restraints meant a decision was also made to design the research in a concurrent fashion. Concurrent processes, that seek to reduce lead times and development costs, have been explored in a variety of fields but most rigorously in the field of mechanical engineering. Syan and Mennon (1994) describe how concurrent engineering is a reaction to the process of sequential engineering, a situation where a new design stage is not started until the previous stage has finished. They contend this latter approach encourages a large number of modifications and alterations in the later stages of development when alterations may be expensive and time consuming. Concurrent engineering attempts to alleviate this problem by integrating all aspects of the design process with the commencement of each distinct stage not being dependent on the full completion of the proceeding stage. This concept is illustrated in Figure 5 where a number of Oppenheim's stages are illustrated in parallel.

Table 10: Research Design Check-list (After Oppenheim 1993)
Conduct a preliminary conceptualisation, i.e. an in depth conceptualisation of the research objectives and the research design.
Design the study and assess its feasibility.
Decide hypotheses to investigate in a case specific manner.
Design research instruments.
Conduct a pilot study.
Sample selection.
Conduct fieldwork..
Prepare information for analysis.
Analysis.
Assemble results and test hypotheses.
Write report.

3.2.2 The Preliminary Conceptualisation

It is suggested by Hakim (1987) that in situations where little is known about a subject, due to its modernity or because of a unique approach, a common starting point for research is, by necessity, a high level phenomenological study based on empirical evidence. A phenomenological study can be defined as one which identifies empirical relationships for observed behavior starting from assumed operating processes (Terwindt and Battjes 1990). A precedent for the use of such an approach in a civil engineering application has been described in Section 1.3 in relation to the TRRL review of reinforced soil applications in developed countries (Jones 1991). Furthermore, it has been demonstrated in the literature review that there has been little research carried out in relation to this subject and that what work there has been has tended to be of an anecdotal nature or has not been related specifically to the frames of reference of this research. Therefore, it was considered reasonable that the method to be used to further assess the way in which techniques for remedial treatment of contaminated land evolve was to be a phenomenological study.

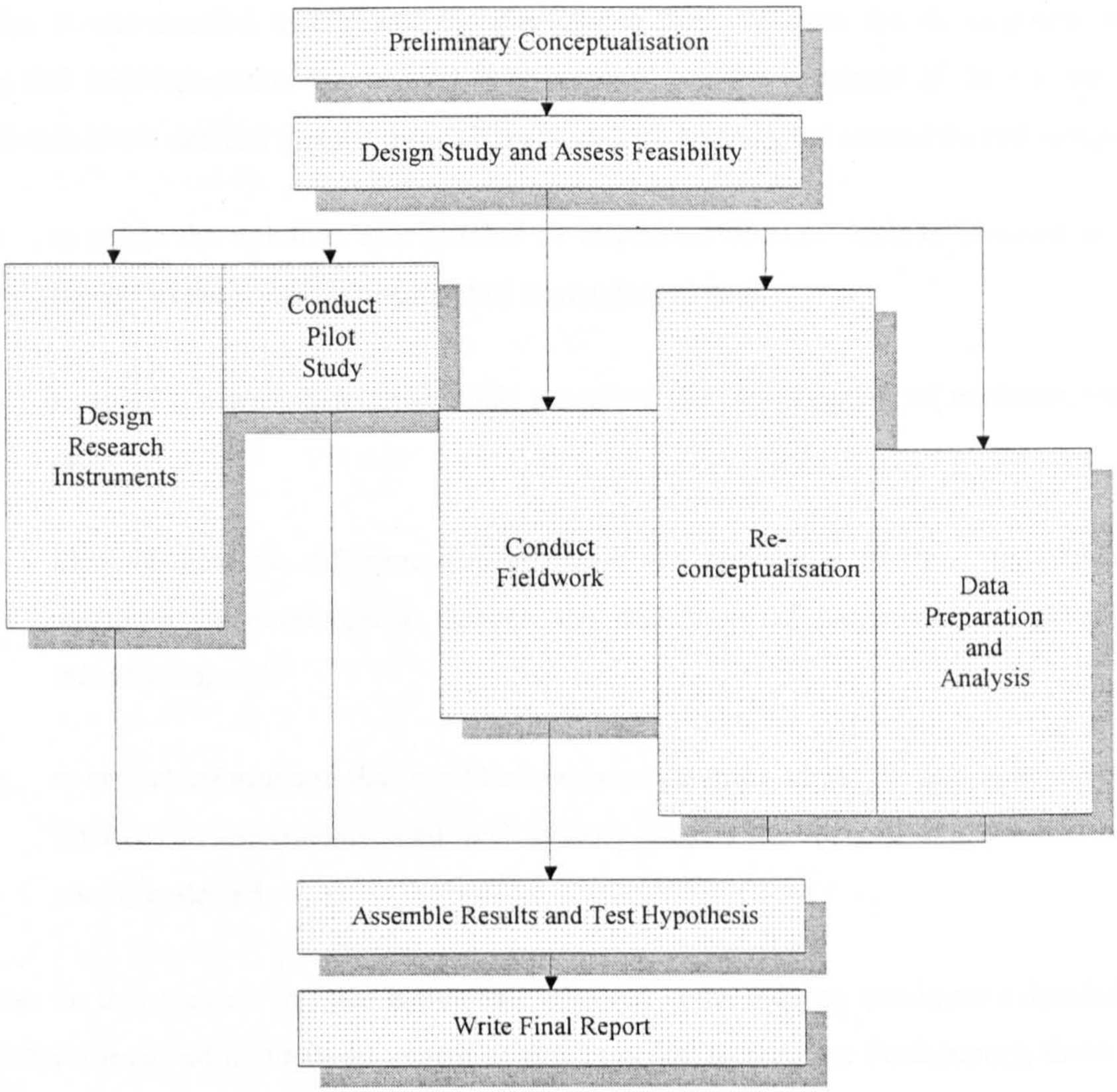

Figure 5: Research Methodology Employing Concurrent Processes (After Oppenheim 1992)

Scott (1992), in his Ph.D. thesis "Project Plans and Record Keeping on Construction Sites in the United Kingdom" also recognised a similar need in relation to the way in which delay claims are dealt with in construction projects. Scott, who's research was based upon information collected in questionnaires, described the uncertainties of an investigation based upon eliciting responses to questions and posed the question "what other way can sensibly be used to identify how engineers and others in various construction related organisations deal with particular problems and to make recommendations as to how they should deal with them?"

Scott recognised that a formal system of dealing with delay claims in construction projects had been developed in the United States and that although no formalised system existed in the United Kingdom the process nonetheless occurred. In addition, it was discussed how this process caused conflict between contractors and engineers and how the judgmental nature of the information that was required was not suited to "traditional" scientific methods of data acquisition. Similarly, it was recognised that similar conflicts, between the diverse elements of the contaminated land industry, influence the dynamics of technological innovation and that these are difficult to quantify.

Specifically, it was decided that it was the phenomena that influence the development of treatment techniques and their *interaction* that needed to be assessed, i.e. the dynamics of the process. In order to accomplish this it was decided that the research methodology be designed around the following aims:

- to gauge the opinions of a number of influential decision makers involved in the various aspects of the remedial treatment of contaminated land;

- to study the way these individuals perceived the development of treatment techniques; in order to

- illustrate how the differences in approach and perception of these individuals effect the dynamics of development through the collection of judgmental or phenomenological information; and

- to collect information that would allow generalisations about the nature of the organisations involved in the contaminated land industry despite the specific or individual nature of the results collected.

The premise for this decision was that individuals involved in the industry would have detailed knowledge of the processes involved in the development of new remedial techniques. Furthermore, these individuals' judgments and perceptions of the way in which the phenomena interact could be used to provide examples of the dynamics of the developmental process. This was to be accomplished by reviewing the information provided by the interviewees, but also by assessing the information they interviewees provided in context. This latter approach assuming that the information the interviewees provided was representative of their particular sector of industry and that this would allow comparisons to be made between the positions held by the various sections of industry. Specifically, it was envisaged that a series of examples, based on the experience of the individuals, that illustrate the dynamics of the process of innovation could be collected. It was reasoned that in this way the effects of certain events or initiatives, e.g. the Cambridge Water case[14] and the United States Brownfields Action Agenda (USEPA 1995a), could be analysed from a number of perspectives, e.g., from the view of consultant engineers, the vendors of remedial techniques, lawyers or policy makers and that the differences in the opinions of these diverse factions could be assessed and used to explain the phenomena which influence the development of techniques for the treatment of contaminated land.

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[14] *ibid* Section 2.2.2

3.2.3 Feasibility Assessment

It was decided that the phenomena would be analysed on the basis of qualitative information collected in a series of interviews. A questionnaire mail-shot was discounted as a method of information collection for the following reasons:

- When using a questionnaire mail-shot it is difficult to ensure the respondents have understood the questions put to them. Mail-shots lend themselves to simple questions and the collection of quantitative as opposed to qualitative information.

- The response rate of questionnaires is invariably poor.

- The diverse nature of the situation to be studied, i.e. the interaction of phenomena as perceived by a variety of individuals in a number of organisations meant that it would be difficult to develop a single questionnaire that would be relevant to all aspects of the situation. The development of a number of questionnaires or a modular questionnaire where different sections could apply to individuals of different backgrounds was ruled out on the basis that it would be difficult to compare the results.

After it had been decided that the collection of qualitative information is best accomplished through the use of interviews the various options were reviewed. May (1993) outlined a number of possible approaches including:

- the **structured interview** that relies on a questionnaire as the primary information collection instrument;

- the **semi-structured interview** that uses structured questions as a base but allows for the interviewer to probe beyond the questions in order to clarify or elaborate the answers; and

- the **focused interview**, or unstructured interview, that is open-ended in character and allows interviewees to talk about the subject in terms of their own "frames of reference".

The structured interview was discounted as it relies on the use of structured questionnaires. Although structured interviews do not present the problems of mail-shot response they are not considered reliable for the collection of detailed qualitative information as they do not allow for any flexibility in the interview approach.

Hakim (1987) suggests semi-structured and focused interview techniques as good methods for establishing the basis of a thesis because when interesting subjects are encountered they can be explored in detail. More rigid methods of questioning cannot allow for this spontaneous approach.

Hakim describes two strengths peculiar to qualitative research methods. The first of these is that is that it allows the study of motivation and other connecting factors. This is a reference to the ability of such techniques to provide information concerning questions that are difficult to ask directly and which may involve a variety of contextual factors that can create links between apparently unconnected matters. The other great strength described is the validity of the data obtained. Hakim argues that individuals are interviewed in sufficient detail for the results to be taken as true, correct, complete and believable reports of their *views and experiences* (emphasis added). Qualitative research is therefore concerned with individuals *own* accounts of their attitudes, motivations and behaviours, and the analysis of these experiences through the use of imposed frameworks which make sense of their experiences. Although qualitative research is about people as the central unit of account, it is not about particular individuals *per se*- reports focus rather on the various patterns, or clusters of attitudes and related behaviour that emerge from the interviews.

Hakim states that the main weakness of such an approach is that "small numbers of interviewees cannot be taken as representative, even if great care is taken to choose a fair cross-section of the type of people who are the subjects of the study". A reasonable sample size for a study with a relatively specific focus is considered to be in the region of 15-25 interviews. This small sample size is justified through the argument that the intention of qualitative studies such as that proposed is not to provide information for statistical manipulation but to explore and develop a model on a preliminary basis in the development of a theory. Consequently, the selection of statistically significant populations or sample groups is not considered of primary importance. Essentially, the work was considered of an exploratory nature and Oppenheim (1992) states "The purpose of the exploratory interview is essentially heuristic: to develop ideas and research hypotheses rather than to gather facts and statistics. It is concerned with trying to understand how people think and feel about the topics of concern to the research".

The research method

A series of both semi-structured and focused interviews was originally decided upon. Each individual was to be interviewed twice- the initial semi-structured interview generating topics that were to be followed up in a focused interview at a later date. However, this choice of interview method was altered when the interview process began. It was not considered practicable that each interviewee be interviewed twice so single interviews were carried out using the focussed approach. This is dealt with in more detail below.

The concurrent research design

As Section 3.2.1 indicates a combination of a research design suggested by Oppenheim (1992) and a concurrent approach was decided upon early in the development of the research methodology. This implied the concurrent implementation of:

1. the design of the research instruments;
2. a pilot study;
3. the fieldwork;
4. the information preparation and analysis; and
5. a continual reconceptualisation.

In practice the barriers between these elements were indistinct. The ways these elements were implemented are dealt with below.

3.3 PROCEDURES

This Section describes how the methodology was implemented in practice. It is divided into the following sections:

1. the method of contacting and briefing interviewees;
2. interview technique; and
3. information preparation/analysis.

These divisions are somewhat arbitrary so it is emphasised that these aspects of the methodology were developed concurrently according to the elements listed above. The following Sections describe how the methodology developed and the reasoning behind this development.

Appendix 1 contains a timetable that was developed during the initial stages of the methodology. It illustrates in detail how the concurrent aspects of the research were organised.

3.3.1 Contacts and Briefings

The theoretical basis

The method of contacting and briefing interviewees decided upon was a combination of Oppenheim's "snowballing" and Foddy's (1993) requirements for ensuring that interviewees give interpretable and comparable answers. Snowballing assumes interviewees will provide new avenues for research and suggestions of other possible interviewees. Foddy, in an attempt to integrate the interaction between interviewer and interviewee into the interview process defines three issues as "especially important if answers are to be interpretable and comparable". These are:

1. the interviewees should have the information actually required of them;

2. interviewees should understand the nature of the questions being asked of them; and

3. the interviewer must specify the perspective that interviewees should adopt when framing their answers.

To address the first of these points, and the argument in Section 3.2.3 concerning the collection of representative information, it was considered important that a reasonably representative cross section of the industry be approached. To this end, a number of categories of potential interviewee were identified:

- policy makers, regulatory and legal;

- industry and services directly related to the remediation of contaminated land, including civil/geotechnical engineering, the financial and insurance sectors and property developers and owners; and

- research or academic institutions.

The practicalities of interviewee selection

The list of interviewees and organisations which was developed was influenced by the following three considerations:

1. The desire to talk to high profile individuals and decision makers in the contaminated land industry. These individuals were identified during the process of the research and included individuals actively involved in contaminated land related research by organisations including: CIRIA, NATO, the Warren Springs Laboratory, ICE, USEPA and UKELA. The value of interviewing such individuals was

considered to be in relation to their breadth of knowledge but also is some cases because of their direct involvement in important events that have shaped the industry.

2. The contacts available to the author through the department. Approaching potential interviewees "cold" (see below) was not considered an effective way of securing participation. Consequently, the use of departmental contacts was recognised as a practical method for the recruitment of interviewees. This had a direct influence of interviewee selection. Specifically, contacts between the department and Judith Denner of the DoE, Golders in the United Kingdom and the United States, GeoSyntec in the United States and the USEPA proved helpful.

3. The need to achieve a representative cross section of the industry. In order to provide balance in relation to the interviewees that were approached, a number of cold contacts were inevitable. This was found to most necessary in relation to contact with remediation contractors, a number of who did consent to be interviewed, but also in relation to property developers and the owners of contaminated sites, the response from whom was poor (see below).

Overall the response to requests for interviews was good, particularly where individuals had links with the department. As a result interviews were conducted with:

- a number of individuals involved with the development and marketing of treatment techniques in the United Kingdom the United States and the Netherlands;
- consultant environmental engineers from a variety of firms ranging in size and scope from small to international from both the United Kingdom and the United States;
- a number of individuals who have been influential in the development of contaminated land policy in the United Kingdom;
- representatives of the USEPA SITE programme and the Technology Innovations Office;
- individuals who have authored state-of-the-art reports and guidance concerning contaminated land from the ICE, DoE and CIRIA; and,
- well known individuals involved with the insurance and legal aspects of contaminated land.

A list of the interviewees by industry sector is provided in Table 14. This illustrates that remedial contractors, environmental consultancy, and policy makers/regulators are all well represented. However, it is also apparent that the owners and developers of contaminated land are not. In order to address this

imbalance- a total of six case studies, based upon the author's work experience, were included in the results. The inclusion of these case studies is discussed more fully in Section 4.1, of the following chapter.

Cold contacts and briefing documents

Contact letters and briefing documents were developed to address the second and third of Foddy's requirements. The third point was reinforced specifically by the briefing documents. These documents outlined the type of information that was being sought. It is emphasised that a conscious effort was made to ensure the interviewees understood the nature of the investigation during the interview process.

The Mk I contact letter and an example of a briefing document are included in Appendices 2 and 3 respectively. The letter outlined the nature of the research being carried out, briefly described how the author considered the potential interviewee could contribute to the research and requested their help in relation to the research. In addition, the letter stated that if the individual was willing to take part in the research a briefing document would be forwarded. Briefing documents were dispatched prior to a meeting to give the interviewee a greater understanding of what was required of them. The briefing document described the research in more detail, gave examples of the type of information that was expected and outlined the interview procedure. It was in the development of the briefing documents that the model of the dynamics of development, that is discussed in Section 5.1 and illustrated in Figure 9, was first used.

The Mk I contact letter was used between October 1995 and January 1996 for the "cold" contact of potential interviewees. The term cold meant that the contacts were unknown to the author. In total nine individuals were contacted in this manner of which eight responded- a result that was considered very successful. Seven of the eight respondents were interviewed whilst the other provided help in the form of contacts within the industry and references considered likely to be useful. Discussion with the interviewees formed the basis for the warm contacts discussed below.

Warm contacts and snowballing

As the process of snowballing occurred the leads on potential interviewees became "warm"- implying some form of contact or familiarity between the author and interviewee. Warm leads were contacted between April and May 1996 using the Mk II contact letter and a briefing document. Ten individuals were contacted of which five consented to be interviewed.

As the research progressed and general patterns began to emerge in the information being collected this began to be reflected in the contact letters. Increasingly it became possible to suggest to potential interviewees how their expertise could be of use in the research. This was reflected in the contact letters that were increasingly tailored to specific individuals. In addition, some leads were contacted on the

telephone or by fax. Consequently, the illustrative example of the Mk II contact letter in Appendix 2 is less representative than the example of the Mk I contact letter.

The Tulip Travelling Scholarship

The Tulip Travelling Scholarship is an award issued by the Department of Civil Engineering, the University of Newcastle upon Tyne, to postgraduate students to enable them to study at approved overseas institutions. The award of this scholarship allowed for research to be carried out in the United States.

An objective of this research is the development of a robust framework for the evaluation of the development of techniques for the remedial treatment of contaminated land on an international basis. Thus, it was assumed that a study of the Superfund regime in the United States would form a part of the research.

Contacts with potential interviewees in the United States were made in the first instance by the author's supervisor and a colleague. Subsequent arrangements were made by the author. The majority of the interviews conducted in the United States were with members of the USEPA. These were arranged via a single contact in that organisation. Other interviews, in the United States, were arranged with consultant environmental engineers in the contaminated land field with links with the author's university department. The briefing document, in Appendix 3, is the one that was developed specifically for the research carried out in the United States.

The follow up procedure and transcript verification

Once transcripts of all the interviews conducted in Europe had been completed they were dispatched to the interviewees for them to make further comments, annotations or changes. The covering letter that was sent with the transcripts is found in Appendix 2. The transcripts were sent out in mid August 1996. The interviewees were requested to return any comments by the start of November 1996. In late October 1996 a final letter was sent out to those interviewees who did not respond to the initial letter. The letter, reproduced in Appendix 2, requested a response. In addition, it stated that if no response was received by a specific date then it would be assumed that the interviewee did not wish to make any corrections. Four transcripts were returned with corrections and additional comments

3.3.2 Information Collection Techniques

Interview development

As already mentioned, it was initially envisaged that two interviews would be conducted with each individual- a focused interview providing the basis for a semi-structured interview at a later time. However, once the interview process began it became apparent that conducting two interviews with each interviewee would be impracticable and unnecessary. This impracticability was emphasised by the fact that the first

interview was conducted in the Netherlands. This revealed that the interviewee could be directed to the areas that were being investigated and that specific examples illustrative of the phenomena sought were readily forthcoming. It was decided that if any further information was required it could be resolved by correspondence. If time and cost had permitted clearly it would have been beneficial to return to the early interviewees.

Discussing the research questions

Focused interviews do not involve a rigid structure. Instead, it is the task of the interviewer to direct the discussion towards the areas of importance. Consequently, it is important that the research methodology is clearly defined in advance so that the interviewer has a clear perception of what information is sought and how to proceed with its collection. This allows provision to be made for the accurate recording of results.

At the beginning of an interview the nature of the research being carried out and the purpose of the interview was made clear. This involved describing the phenomena identified in Section 2.7 as factors that influence the evolution and development of techniques for the remedial treatment of contaminated and that the aim of the research was to identify detailed examples of these phenomena. In addition, a number of examples of the type of information being sought were indicated. The discussion was then directed towards the consideration of specific examples of these phenomena. Interviewees were asked if they could give illustrative examples of the phenomena being studied or asked to comment on one of the examples given by the author.

Once an interview began it was usual for the discussion to flow relatively spontaneously. However, it was occasionally necessary to direct the discussion by making reference to the phenomena being studied in order to stimulate the conversation or ensure relevant subjects were explored. Initially, the task of directing the interviewees towards specific areas of conversation was difficult. This was emphasised by the author's unfamiliarity with both the interview process and the relevance of some of the information that was being collected- something that was noted when the interview transcripts were being produced (see below). Consequently, in the early interviews there was a tendency for the discussion to be of a general nature and to jump from topic to topic. This problem became less of an issue as the author became generally more experienced in the process of conducting the interviews but also because a familiarity with the research topics developed that allowed the discussion to be kept within more strictly defined limits.

Recording the information

May (1993) makes the point that raw field notes written in shorthand during a conversation can be unintelligible to readers other than the author. It is also emphasised that notes may lose their meaning after some time has elapsed. For these reasons interview write-ups were completed as soon as possible after the event to ensure the information was as accurate as possible and that any nuance or meaning evident during

the interview was not lost. It was necessary that once written up the transcripts would be intelligible to anyone and not just the author.

Particular emphasis was placed on the use of a logbook to record the discussions and to counter the potential disadvantages of the focussed approach. As stated above there were problems with the recording of the results in the earlier interviews as the notes that were made tended to jump around between the research questions. However, this was due to a lack of experience rather than poor note taking- although the solution lay partly in using reflective and marginal remarks to note when a comment applied to one of the research questions. Again this task became easier with experience and as it became easier to orientate the discussions in particular directions.

Reflective remarks were made during the interview process with the intention of applying context to the information. Examples of reflective remarks included:

- thoughts on the meaning of what an interviewee is saying;
- doubts about the quality of the information being recorded;
- a new hypothesis explaining what is happening;
- a mental note to pursue an issue further;
- cross-allusions to something in another part of the information; and
- elaboration or clarification of something said or done.

Marginal remarks were used to add further detail and thoughts immediately after an interview had been conducted.

The questionnaire

It was anticipated at the outset of the research that the initial interviewees may need to be approached at the end of the research period to clarify those aspects that may not have been obvious at the beginning of the interview process. To address this it was decided that when the transcripts of the interviews were sent out to the interviewees a questionnaire would also be included. The questionnaire, included in Appendix 5, contains questions that emerged during the preliminary analysis of the European interviews. The questions represented the general trends that could be seen to be emerging during the information processing and sought clarification of these trends. It also requested criticism of the research method used. The questionnaires were sent to all the European interviewees and those respondents to the Mk I and II contact

letters who were not interviewed. In total nine completed questionnaires were returned, seven by interviewees and two by individuals who were not interviewed.

3.3.3 Preparing the Information for Analysis

The task of preparing the interview transcripts for analysis again highlighted the unfamiliar territory this research entailed. In order to gain meaning from the information collected in the interviews it was recognised that that some form of information analysis was required. A study of qualitative information analysis (Miles and Huberman 1984; Wolcott 1994) revealed a variety of possibilities. However, none seemed to provide an ideal method. Complicated methods of qualitative analysis such as coding were not considered necessary and not applicable to the nature of the focussed interviews. In addition, the use of matrices to represent the results visually was considered in some detail and appeared to have some potential. However, this was also rejected as although the opinions of the interviewees could, superficially, be grouped together the diverse nature of their experience defied graphical representation.

Penultimately, a method of dividing the information according to its relevance to the following phenomena was developed:

1. What is the influence of public awareness?
2. What is the influence of business awareness?
3. What is the influence of technical improvement?
4. What influence do measures to stimulate innovation have?
5. What influence do policy instruments have?
6. Are there any other important factors that have been overlooked?

The transcripts and returned questionnaires were read through in detail and each substantial point made by an interviewee or respondent was allocated to one of the research questions. However, as the interview process progressed it became clear that the information being gathered was of an increasingly complex nature. As a result it became difficult to allocate the comments made by the interviewees to single categories. Consequently, this method was also rejected as a form of information presentation- although it proved useful as it contributed to the author's familiarity with the information and enhanced the process of analysis. Accordingly, a distinction is drawn between the ultimate presentation of information and its

analysis. It was finally decided that the information would be presented as a series of summaries. The justification for this decision is given in Chapter 4 Section 4.1.1.

3.4 SUMMARY

The qualitative nature of the information sought by this research made the development of a methodology an intriguing task. The unfamiliar nature of the research methods commonly used for the collection of such information meant that not only did the research methodology need to be selected and justified but also the reasoning behind these choices was required.

The decision to review the methodology continuously to allow it to develop concurrently appears to have been vindicated in light of the author's accumulating experience of qualitative research methods. The fact that the reconceptualisation and concurrent development were deliberate meant that when it became apparent that, for example, the decision to conduct two interviews with each individual could be seen to be impracticable- then the research methodology could be readily evolved. The learning curve was steep but this was expected and appropriate. The concurrent approach was again useful when planning, organising and writing up the interviews. These stages are described separately above. However, during their development and implementation these elements tended to be considered as a single process: the briefing of the interviewees influencing the interview; the amount of interview experience influencing taking of notes; and, the writing up of notes influencing the way the interview was conducted.

Finally, the method of presenting the information gathered in the interviews was ultimately selected. The following chapter contains the results that were produced by the methods of information preparation detailed above

4. RESULTS

4.1 OVERVIEW

Chapter 3 described the development of a concurrent methodology that used interviews as the primary method of collecting information. Chapter 4 presents this information as a series of short summaries. The aim of this chapter is to provide a succinct account of the information collected and to demonstrate its validity both in terms of the roles of the individuals interviewed and the nature of the information collected from them.

In Section 4.1.1, an account of the method of interview presentation employed in this chapter is given. In addition, the decision to use case study information to supplement the interview information is discussed. Summaries of the full interview transcripts (provided in Appendix 5) and contextual information relating to the interviewees are presented in Section 4.2. In Section 4.3, six case studied based upon the author's work experience are presented. An explanation of the chapter's relevance to the discussion in Chapter 5 concludes this chapter.

4.1.1 Explanation of the Results

The Interview Information

It is emphasised in Section 3.3.3 that as this research progressed, the information collected from the interviewees began to resemble arguments rather that simple remarks and opinions. As these arguments were only considered coherent when considered in their entirety and in context, it was decided that the results be presented as a series of synoptic summaries.

However, the simple reproduction of the information as a summary is not the aim of this chapter. As Perry (1994) states, the information in a results chapter "should not merely be presented and the examiner expected to analyse it". Consequently, in addition to the summarised version of the full interview transcript, each summary includes an account of the context in which the interview was conducted and the information summarised in Table 11. This contextual information reveals the basis on which the interviewees base their opinions and is therefore useful in the interpretation of their comments. This is because it is the consideration of the information provided in context which facilitates its critical assessment. Indeed, it is considered appropriate to further emphasise Hakim's argument (see Section 3.2.3) that focused interviews allow individuals to be interviewed in sufficient detail as their comments to be

taken as believable reports of their *views and experiences*- as this illustrates the need for contextual information.

A total of 22 interviews were conducted in the United Kingdom, the Netherlands and the United States. The interviewees are listed in Table 12. The interview transcripts, detailed in Appendix 5, and their summarised versions that follow are based upon notes taken during the interviews listed in Table 12 and also upon amended interview transcripts and questionnaires. Table 13 lists those interviewees who responded to a request to amend a copy of their interview transcript or complete a questionnaire. Four interviewees chose to amend manuscripts and six returned completed questionnaires.

Table 11: Example Results Table	
Name: Dr A. N. Other	**Organisation:** Any Org
Basis of the information: interview, questionnaire, seminar or lecture	**Location of full transcript:** Page x
Context: This includes information on the background and occupation of the interviewee and details of their employment. (This information is also summarised in table form in Table 12, Table 13, and Table 14). The intention of this section is to ensure the opinions of the interviewees are considered in context.	
Summary: A summary of the full interview transcript, found in Appendix 5, and any information provided in a returned questionnaire is given. The intention of this section is: to provide a succinct account of the information collected by the interview, lecture, seminar or questionnaire; and to highlight, in the author's opinion, the most important points.	

Table 12 also illustrates that, in addition to the twenty two interviews, in five cases the information summarised below is wholly based upon lectures, seminars and questionnaires. Specifically, the information from Prof. Judith Denner is based upon a lecture; the information from both Malcolm Lowe and Professor Malcolm Grant is based upon seminars; and the information from Stephen Tromans and Jim Begley is based upon questionnaire returns. The information from Brian Street, Tony Lennon and John Warr is based upon both an interview and a seminar.

The Case Study Information

Section 3.3.1 emphasised the importance of approaching individuals from a cross section of the contaminated land industry. Table 14 lists the interviewees and questionnaire respondents according to their area of expertise. Six have experience in the operation of treatment techniques, six work in environmental consultancy, nine work within government, one for a chemicals company, one in the

environmental insurance industry, one in the field of environmental law, and one within academia. This cross section well represents the diverse factions involved in the contaminated land industry, albeit with a bias towards consultancy and the vendors of treatment techniques, but with one exception. It is apparent from Table 14 that the contaminated land problem holders are conspicuous by their absence. The Appropriate People (AP), Responsible Parties (RPs) and Potentially Responsible Parties (PRPs) that can be identified by British or American law and the owners or developers of derelict or brownfield sites are not represented. This deficiency was noticed in the process of this research and is attributed to a reluctance amongst representatives of these groups of individuals or companies to comment on their situation due to its sensitive nature.

In order to rectify this deficiency, the author has drawn upon work experience gained as a consultant environmental engineer, and specifically on those situations where the use of treatment techniques has been a possibility. These experiences, as outlined in a series of case studies, concentrate on the way in which remedial strategies have been developed for these sites and the influences on the choice of remedial techniques. These decisions are directly influenced by the owners and developers of these sites but also by other factors including managerial constraints, technical limitations of the treatment techniques and ground conditions. The cases provide practical insight into the factors influencing the use, and consequently the development, of treatment techniques, and therefore help to address the limitations of the data gained through interviews. A list of the organisations that were involved in the case studies is provided in Table 15, the names of the organisations involved have not been disclosed for reasons of confidentiality. The case studies are based on the following projects:

1. The remediation of diesel contamination in light industrial units and their redevelopment as warehouses and offices in the south east of England

2. The remediation of petroleum hydrocarbon contamination at a former fuel storage depot and its redevelopment as a residential development in the south east of England

3. The remediation of heavy metal and PAH contamination at a former psychiatric hospital and its redevelopment as a residential development in the south east of England

4. The remediation of diesel contamination at a builders yard and its redevelopment as offices in the south east of England

5. The investigation of a former industrial site and its potential for redevelopment for retail and leisure purposes in the north east of England.

6. The investigation of a former industrial site and its potential for redevelopment for residential use in the south east of England.

With the exception of case 6, all of these cases involve contamination by organic pollutants. In addition, cases 3 and 5 also involve contamination by heavy metals. However, the contamination present has diverse causes and the proposed end uses of the sites differ. The presence of organic contaminants at these sites makes a comparison of the use of biological treatment techniques possible. Biological techniques are relatively well established in the United Kingdom, they are specifically used in the degradation of organic contaminants. Indeed, Martin & Nathanial (1998) contend that biological techniques are the only treatment technique to be used in more than a "handfull" of cases in the United Kingdom, although they do base their assumptions on examples reported in open lterature.

The original site uses differ although three are contaminated by fuel spills or leaking fuel tanks and the other two by PAH. In none of these cases are the heavy metal concentrations so high as to reduce the effectiveness of biological treatment techniques, consequently, all these sites could potentially be treated with biological techniques. Biological treatment techniques have been considered for all but Case Study #4 and to date have been rejected for use in two cases (Case Studies #2 & #3), accepted in one (Case Study #1) and is being considered for the last of these (Cast Study #5).

These cases have revealed a variety of factors which influence the decision to remediate contaminated sites and in particular with relation to biological treatment techniques in practical situations. The implications of the case studies are discussed further in Chapter 5 in conjunction with the discussion of the interview and questionnaire results.

Table 12: List of Interviewees and Questionnaire Respondents

Interview #	Interviewee	Organisation	Interview Date	Full Transcript
1	Dr R. Lageman	Geokinetics (Netherlands)	25/10/95	8-192
2♠	Brian Street, Tony Lennon & John Warr	ECS Underwriting & Fielding Smeaton & Jones	13/11/95 and 23/11/95	8-194
3♣	Prof Judith Denner	DoE	25/01/95	8-200
4	Dr Mary Harris	Monitor Environmental (formerly Clayton)	31/01/96	8-205
5	Philip Crowcroft	Aspinwall & Company	12/03/96	8-211
6	Kelvin Potter	ICI	4/04/96	8-217
7	Neil McLeod	Envirotreat Ltd	10/05/96	8-222
8	Mark Dyer	Mark Dyer Associates	15/05/96	8-226
9	Ian Burbidge & Cameron M. Scott	Graesser International	3/06/96	8-230
10	Gavin Costigan	DTI and JEMU	12/06/96	8-232
11	Glenn Jones	Biolytic	17/06/96	8-235
12	Brian Lassmann	Eco-Logic	4/07/96	8-237
13	Linda Fiedler	USEPA TIO (Washington D.C.)	17/09/96	8-238
14	John Martin	USEPA (Cincinnati)	19/09/96	8-240

♠: Indicates results based upon a seminar.

♣: Indicates results based upon a lecture.

♥: Indicates results based upon questionnaire only

List of Interviewees and Questionnaire Respondents - Continued

Interview #	Interviewee	Organisation	Interview Date	Full Transcript
15	Michelle Simon	USEPA (Cincinnati)	19/09/96	8-242
16	Edwin Barth	USEPA (Cincinnati)	19/09/96	8-244
17	Round Table Discussion	USEPA (Cincinnati)	20/09/96	8-245
18	Ed Bates	USEPA (Cincinnati)	20/09/96	8-247
19	Kandi Brown	IT Corporation (California)	20/09/96	8-249
20	Neil Davies	Geosyntec (Atlanta)	23/09/96	8-251
21	Randy Sullivan	Golders (Atlanta)	24/09/96	8-253
22	Dr Stephan Jefferis	Golders (UK)	12/11/96	8-256
23♠	Malcolm Lowe	DoE	20/11/96 and 26/11/96	8-258
24♠	Prof Malcolm Grant	University of Cambridge	29/11/96	8-260
25♥	Stephen Tromans	Simmons and Simmons	N/A	8-261
26♥	Jim Begley	AEA Technology	N/A	8-263
27	Prof Raymond Yong	Cardiff and McGill Universities		

♠: Indicates results based upon a seminar.

♣: Indicates results based upon a lecture.

♥: Indicates results based upon questionnaire only

Table 13: Transcript and Questionnaire Returns

Interview Number	Interviewee	Transcript returned with alterations	Questionnaire returned
1	Dr R. Lageman	×	×
2	Brian Street	×	×
3	Prof Judith Denner	×	×
4	Dr Mary Harris	✓	✓
5	Philip Crowcroft	✓	✓
6	Kelvin Potter	✓	✓
7	Neil McLeod	×	✓
8	Mark Dyer	×	✓
9	Ian Burbidge	×	×
10	Gavin Costigan	✓	✓
11	Glenn Jones	×	×
12	Brian Lassmann	×	×
N/A	Stephen Tromans♥	N/A	✓
N/A	Jim Begley♥	N/A	✓

♥: Indicates results based upon questionnaire only

Table 14: List of Interviewees by Industry Sector

Area of Work	Interviewee	Organisation
Remediation	Brian Lassmann	Eco-Logic
	Dr R. Lageman	Geokinetics (Netherlands)
	Glenn Jones	Biolytic
	Ian Burbidge	Graesser International
	Kandi Brown	IT Corporation (US)
	Neil McLeod	Envirotreat Ltd
Consultancy	Dr Mary Harris	Monitor Environmental
	Mark Dyer	Mark Dyer Associates
	Neil Davies	Geosyntec (US)
	Randy Sullivan	Golders (US)
	Dr Stephan Jefferis	Golders (UK)
	Jim Begley	AEA Technology
	Philip Crowcroft	Aspinwall & Company
Government	Malcolm Lowe	DoE
	Prof Judith Denner	DoE
	Gavin Costigan	DTI and JEMU
	Linda Fiedler	USEPA TIO
	John Martin	USEPA
	Michelle Simon	USEPA
	Edwin Barth	USEPA
	Round Table Discussion	USEPA
	Ed Bates	USEPA
Chemicals	Kelvin Potter	ICI
Insurance	Brian Street	ECS Underwriting
Legal	Stephen Tromans	Simmons and Simmons
University	Prof Malcolm Grant	University of Cambridge
	Prof Raymond Yong	University of Cardiff and McGill University

Table 15: List of Organisations Involved in Case Studies
Area of Work
Property Developers
Property Owners
Local Authorities
The Environment Agency
Estate Managers
Specialist and General Remediation Contractors
Site Investigation Contractors

4.2 INTERVIEW AND INTERVIEWEE SUMMARIES

4.2.1 Dr R. Lageman	**Organisation:** Geokinetics (Netherlands)
Basis of the information: interview	**Location of full transcript:** Page 8-192

Context: Dr Lageman is the director of Geokinetics Ltd. He founded Geokinetics Ltd in 1988 with a local government grant of NGL80000 and NGL1 million venture capital. The company is now partly owned by A.hac Ltd who provide office and lab space and funding for experimental work. Geokinetics are attempting to develop a suite of commercially viable electro-kinetic techniques. They are currently involved in a joint venture with AEA Technology developing electrokinetic active containment systems. This account was produced after a meeting at the offices and laboratory of Geokinetics Ltd in Rhenen, The Netherlands.

Summary: Geokinetics offer two remedial techniques: electro-remediation for the in-situ removal of inorganic and organic contaminants; and electro-heating for the in-situ heating and removal of volatile and semi volatile organic compounds. Electro-remediation removes both inorganic and organic contaminants and is therefore not cost effective in the majority of situations, i.e. where only organic contaminants are present. However, electro-heating is used solely for the removal of organic contaminants and is therefore more cost effective. This technique is now in constant use both internally within A.hac and as a commercial process.

The process of field testing is vital in the development of remedial techniques. Field testing has revealed the advantages of process integration; given an insight into the practical use of remedial technology; and allowed for the building of plant and the development of efficient procurement procedures.

The market for, and the regulation of, contaminated land is still immature. However, there will be a boom in the use of technology, as opposed to consultancy, when negative land values affect the balance sheets and share prices of large companies. This will create a market for large scale clean-up projects.

The Dutch are especially concerned with groundwater problems. Consequently, remediation, as opposed to encapsulation, is the predominant method of dealing with contaminated land in the Netherlands. The Dutch system of regulation is too restrictive. However, it has enabled the development of techniques for the treatment of contaminated land. There are moves in the Netherlands towards more realistic legislation and a regulatory system akin to *suitable for use*.

4.2.2 Brian Street, Tony Lennon and John Warr	**Organisation:** ECS Underwriting (Street and Lennon) and Fielding, Smeaton and Jones (Warr)
Basis of the information: interview and seminar	**Location of full transcript:** Page 8-194

Context: Claims arising from environmental liabilities have dealt the insurance industry a sever blow in recent years. ECS Underwriting are one of a select band of insurers that have embraced environmental liability and offer specific cover on a long term basis. Brian Street is an outspoken commentator in the field of contaminated land in the United Kingdom. A staunch critic of the recent attempt to promote caveat emptor as a solution to the problems of contaminated land and of the dangers of introducing joint, strict, retroactive liability to the United Kingdom. The discussion also included Tony Lennon, an underwriter with ECS who used to work as an inspector for HMIP, and John Warr, an insurance broker who specialises in environmental insurance. The interview took place in the Offices of ECS Underwriting and Fielding Smeaton and Jones in London, United Kingdom. Information was also gathered at a seminar held in Edinburgh, United Kingdom.

Summary: The joint and several, strict, retroactive liability introduced by Superfund resulted in the collapse of the American insurance market and £8 billion losses for Lloyd's. European legislators are following this same path and consequently the insurance industry faces vast claims relating to public liability (PL) policies issued prior to 1991 when a pollution exclusion was introduced. The contaminated land provisions in the Environment Act 1995 will increase the incidents of claims under PL policies although many companies, insured after 1991, may be without insurance cover for environmental liabilities related to contaminated land remediation orders. Cover is available for such liabilities although at a cost. An Environmental Impairment Liability (EIL) policy will cost a minimum of £15000 and require a site investigation. Many smaller firms will not be able to afford this cover. EIL cover is a means of overcoming the potential for land blight caused by contaminated land regulations. Cover provides the following benefits: leading regulators to view a company favorably; reassurance to financial institutions; protection of land as an asset; safety from environmental liability; and increased attractiveness to potential buyers.

4.2.3 Prof Judith Denner	**Organisation:** DoE (EA)
Basis of the information: lecture	**Location of full transcript:** Page 8-200

Context: At the time of the lecture Prof Denner was the Head of the Contaminated Land and Liabilities Division (CCLD) of the Department of the Environment. As such she was responsible for overseeing a review of contaminated land in the United Kingdom; the publication of Framework for Contaminated Land (DoE 1994a); and the drafting of the contaminated land provisions in the Environment Act 1995. She is no longer at the Department of the Environment but has been appointed Head of Contaminated Land at the Environment Agency. The following abstract is based upon a lecture given by Dr Judith Denner, in her capacity as visiting Professor, in the Geotechnical Group at Newcastle University, United Kingdom.

Summary: The CCLD of the DoE has two primary policy objectives. These are: to remove unacceptable actual or potential risks to health or the environment; and bring contaminated land back into beneficial use by the most appropriate and cost-effective means.

It is because of the success of the planning system that the United Kingdom can come up to speed in relation to the regulation and redevelopment of contaminated land. Section 143 of the Environmental Protection Act 1990 failed because of political lobbying but also because it did not conform with the Department's overall policy objectives. In contrast, *suitable for use* is the philosophical extension of the planning system. It provides a pragmatic system for the regulation of contaminated land by encouraging voluntary, planning led redevelopment. This approach is at odds with prescriptive technological requirements. However, environmental incentives have been considered in order to encourage the use of techniques for the treatment of contaminated land and more generally the Derelict Land Grants and English Partnerships encourage remedial treatment.

It is difficult to cherry-pick the best aspects of other nations regulatory approaches as the success of a policy depends upon the policy framework in place. e.g. how projects are funded; the method of risk assessment used; the application of technology; the provisions of private law; and the administrative regimes in question.

4.2.4 Dr Mary Harris	**Organisation:** Monitor Environmental (formerly Clayton)
Basis of the information: interview, with revisions by Dr Harris, and questionnaire	**Location of full transcript:** Page 8-205

Context: Monitor Environmental Consultants (formerly Clayton Environmental) operate in a range of environmental fields but particularly in relation to contaminated land. Dr Harris has over 15 years experience in the contaminated land industry. She is an author of the CIRIA Report on Remedial Treatment for Contaminated Land (Harris *et al* 1995) and also of the author of the ICE Design Guide on Contaminated Land (Harris and Herbert 1994). Currently, Dr Harris is a sub contractor on a DoE funded contract to prepare standard procedures on the identification, assessment, treatment and monitoring of contaminated land. The following account was produced after a meeting with, and subsequent revisions by, Dr Mary Harris. The interview was conducted at the offices of Clayton Environmental Consultants Ltd, Birmingham, United Kingdom.

Summary: The United Kingdom's approach to the regulation of contaminated land developed out of the land use planning system and public health provisions. The Section 143 Registers failed partly because they elevated contaminated land to being an environmental issue as opposed to a redevelopment issue. The provisions for contaminated land in the Environment Act 1995 are there to prevent *significant* threats to human health and the environment that cannot be dealt with by existing legal controls.

In the past civil engineering methods tended to be used to deal with the poor physical conditions of derelict land. However, managing contaminated land involves a number of disciplines including biological and chemical engineering expertise. As awareness of soil and groundwater contamination increases then the need for techniques for the treatment of contaminated land will increase. The need to deal with effects on water will be one of the main reasons for the use of new technologies. In the United Kingdom a prescriptive risk assessment system in unlikely to be introduced. There will be a recommended generic approach and, if users wish to depart from this, they will have to be prepared to justify their actions on technical grounds.

A great deal of money has been spent in the United States developing remedial techniques. However, as the need to redevelop brownfield sites increases it is becoming clear that some sites will have to be contained, although, containment in the United States has been widely seen as a temporary measure, the primary objective always is total clean-up. In the United Kingdom properly designed containment is a viable solution in its own right.

Dr Harris perceives a number of barriers to the development of new remedial techniques: the price and volatility of landfill; problems regarding quality assurance and liability; and the perception that testing remedial techniques on a site specific basis is an additional unwanted cost.

In response to the questionnaire, Dr Harris suggested: Figure 9 could represent the market for remedial techniques in the future- pushing to find technical solutions in parallel with the basic framework provided by policy and law; that technical and administrative uncertainty represented a barrier to the performance of innovative techniques; and, that independent verification and field demonstration of technology helps the vendors of remedial techniques.

In relation to markets and policy development she made the points that the state has a responsibility to ensure that the pubic funding of scientific advancement clearly results in public benefit; that there will be recognition that it is unlikely that we shall ever be able to bring land back to its pre-industrial condition and that cost is the factor that will drive the prioritisation of health risks in this situation.

Successful remedial techniques will include: active barriers, ex-situ modular techniques, and in-situ techniques that: can be used on site, provided they are applicable to a variety of contaminants; are reliable; and, offer low capital maintenance and operational costs. She sees an increased awareness and willingness to address contaminated land issues as one of the main opportunities for developers of remedial techniques.

4.2.5 Philip Crowcroft	**Organisation:** Aspinwall & Company
Basis of the information: interview, with revisions by Mr Crowcroft, and questionnaire	**Location of full transcript:** Page 8-211

Context: Aspinwall & Company are a medium sized environmental management consultancy based in Shrewsbury, in the United Kingdom. Much of their work relates to contaminated land and environmental policy. Philip Crowcroft is Head of the Water and Land Development Group at Aspinwall & Company. He is the author of a number of papers on the barriers to the development of techniques for the treatment of contaminated land. The following account was produced after a meeting with, and subsequent revisions by, Mr Philip Crowcroft. The interview was conducted at the offices of Aspinwall and Company, Shrewsbury, United Kingdom.

Summary: There was a view in the late 1980s that a boom in the use of remedial technology was imminent, however, the economy went bust and any potential markets for many remedial techniques disappeared.

Contaminated land issues tend to remain local in the United Kingdom, possibly because the United Kingdom has not experienced an incident such as the Love Canal.

The civil law and current contaminated land legislation is inherently weak. Section 57 of the Environment Act 1995 will not draw in a large number of sites, although, it may encourage the pre-emptive clean-up of land. Although the NRA and the EA have powers they will not be fully enforced and developers will wait and see what are the minimum requirements. This will dictate the level of compliance in the country because there will not be the money to carry out the remedial works that the regulators could legally require. In addition, the agencies do not wish to become involved in the legal battles that would, they feel, follow. There is a reluctance to follow the Superfund route of chasing polluters through the courts for the costs of clean-up.

Successful techniques will be developed from crossovers from other industries. Of the existing techniques soil washing and active containment have promise.

There is market for techniques for the treatment of contaminated land in the United Kingdom. Indeed, the landfill industry see treatment techniques as a competitive threat, so much so that operators are actively cutting costs to undercut some remedial techniques. In addition, some landfill operators are having to take waste at a loss.

In response to the questionnaire, Mr Crowcroft suggested Figure 9 was a reasonable representation of reality but that the importance of cost as a driving force should be enhanced. Uncertainty exists in relation to whether encapsulation is safe, who should decide this, and whether the price and quality of remedial techniques can be assured. Confidence in remedial techniques will come through the demonstration of techniques and when the costs of landfill rise. The developers of new remedial techniques need to concentrate on establishing a track record, sharing their costs and benefits with clients or seeking funding for early development work.

Contaminated land cleanups will become increasingly risk based and be based on a *suitable for use* approach. The global market for remediation will continue to develop quickly in mainland Europe and North America due to high landfill prices. There will be little development in South East Asia.

Successful remedial techniques will be: cheap, flexible, effective, mobile and able to operate without permits. This could involve the use of: biosparging, positive air pressure, leachability reduction and active containment.

Threats to the development of techniques for the treatment of contaminated land are: the Landfill Tax exemptions; cheap landfill and a lack of funding for research. The increased awareness of contaminated land issues provides the best opportunity.

4.2.6 Kelvin Potter	Organisation: ICI
Basis of the information: interview, with revisions by Mr Potter, and questionnaire	**Location of full transcript:** Page 8-217

Context: Mr Potter emphasised at the outset that he was speaking in his capacity as an Intelligent Manufacturing Systems (IMS) project leader and not as an ICI employee. The opinions expressed do not necessarily reflect opinion within ICI. The IMS10 project involved a study of over 100 leading personnel from the chemical and pulp and paper industries, from regulators, consultants and contractors, and academia in 10 countries. The aim of the project was to identify how remedial techniques are selected and to identify common areas of uncertainty and concern that could be solved by collaborative R&D. He is also involved in the NICOLE project- an industry led initiative sponsored by DGXII of the European Commission that aims to disseminated scientific and technological information concerning contaminated land and groundwater. In addition, he was chairman of the committee responsible for the production of the CIRIA report on selection and classification of remedial techniques (Harris *et al* 1995a). The following account was produced after a meeting with, and subsequent revisions by, Mr Kelvin Potter. The interview was conducted at the offices of ICI, Runcorn, United Kingdom.

Summary: Large multinational companies first began to recognise the problems associated with contaminated land in the early 1980s when the Love Canal disaster received widespread recognition. This incident has moved into American folk law and illustrates a tendency in the United States towards overreaction. Consequently, United States firms became fearful of unrealistically onerous and retrospective liability and reacted obstructively.

The risks involved with contaminated land are emotive and not widely known or understood. There is a growing realisation of this in the United States and there are moves afoot to move towards a more pragmatic approach similar to that in the United Kingdom. Both IMS10 and NICOLE illustrate that multinational companies and governments are promoting initiatives to both illuminate and address efficiently the problems of contaminated land.

In response to the questionnaire, Mr Potter stated that figures illustrating the development of remedial techniques were confused. He stated that the development of remedial techniques depends on the nature of the regulatory culture in which the market exists and that prescriptive environments encourage the development of existing technology and new techniques whilst pragmatic regimes place the emphasis on the incremental reduction of cost.

In the early stages of development remedial techniques were portrayed as panacea. Their failure to perform

set them back. To gain credibility and experience the vendors of remedial techniques should: test in the field and lab; participate in verification schemes; apply for funding; share the potential risk and benefits with interested parties; and lobby for support.

Contaminated land policy is increasingly based upon risk and *suitable for use* criteria. It is also moving toward longer time frames for remedial action. Extravagant estimates of the cost of remediating the legacy of contaminated land will not materialise, partly as a result of proper assessment of the significance to health and the environment of contaminated land, and partly as a result of contaminated land issues maintaining a low public profile.

Successful remedial techniques will be: easy to install; low cost; low maintenance; and relatively long term. This could involve: natural attenuation; in-situ biotreatment; and active containment. Threats to the developers of remedial techniques involve: the shrinking of the market when the real risks of contamination are discovered; not having a track record; being uncompetitively priced; acquiring NIMBY status; and overcoming the time it takes to be accepted in the market and by regulators. Opportunities are: initiatives to encourage remediation; European Union funding; and operating in niche markets.

4.2.7 Neil McLeod	**Organisation:** Envirotreat Ltd
Basis of the information: interview and questionnaire	**Location of full transcript:** Page 8-222

Context: Envirotreat Ltd entered the remedial treatment market in 1990 offering chemical stabilisation techniques that were developed in association with Birmingham University and May Gurney Ltd. Between 1990 and 1993 they were involved in the DoE/DTI Environmental Technology Initiative Scheme (ETIS). More recently their techniques were evaluated by the NATO/CCMS study on contaminated land. In 1995 Envirotreat began work on the use of modified slurry trench walls for active containment. The following account was produced after a meeting with Mr Neil McLeod, the technical director of Envirotreat, at their offices in Kingswinford, West Midlands, United Kingdom.

Summary: The lack of optimism in the United Kingdom remediation market is illustrated by the number of environmental consultancies curtailing their contaminated land operations. Vendors of remedial techniques have been adversely affected by recent policy decisions. e.g.: the withdrawal of the Section 143 Registers; the exemption of contaminated soil from the Landfill Tax; and delays relating to the issue of statutory guidance on contaminated land.

Envirotreat used the USEPA leachability standards as benchmarks when developing their technology. It was realised that new techniques must be demonstrable. This helped secure ETIS funding for their role in the development of standards for in-situ remediation. This afforded Envirotreat both funding and kudos.

Differences in markets for remedial techniques between the United Kingdom and United States can be attributed to land values. In the United States and Australia industry is spread out; relatively more recent; and contamination is easier to trace and define. Consequently, Superfund is the mainstay of the contaminated land industry. Conversely, few United Kingdom firms develop technology- the majority is franchised from the United States or Europe. In addition, the exemption of contaminated soil from the Landfill Tax will prevent the development of remedial techniques in the United Kingdom and promote the use of landfill.

The United States cannot pull back from their stringent requirements for remediation although a more risk based system will be used. However, Europe may move to a more pragmatic approach.

Most remedial techniques cannot compete with landfill on a cost per ton basis. Consequently, remedial techniques may only be able to function in specific niches. Europe will concentrate on central processing facilities and America on mobile facilities. An understanding of the market and the needs of developers led

Envirotreat to the decision to develop active containment and to emphasise the unique benefits such techniques offer.

In response to the questionnaire, Mr McLeod agreed with the general principle represented in Figure 9 but stated it was somewhat simplistic. Envirotreat overcame uncertainty in their technique by basing their technology on existing techniques and by gaining credibility through support by the DoE. It is also important to field test a technique, although, without experience it is difficult to organise such tests.

The state has a responsibility to clarify standards and target objectives. Such standards are slowly being developed although the perceived environmental market is significantly higher than the availability of funding to support remediation.

Successful techniques will be those which are technically sound, cost effective and can be practically applied. Lack of government support in introducing meaningful standards and a lack of political willpower to discourage landfilling are threats to the developers of remedial techniques.

4.2.8 Mark Dyer	**Organisation:** Mark Dyer Associates
Basis of the information: interview and questionnaire	**Location of full transcript:** Page 8-226

Context: Mark Dyer Associates provide specialist R&D consultancy on geotechnical and environmental engineering to the Environment Agency and the EPSRC. Mark Dyer has particular interest in the allocation of research funding in geotechnics. The following account was produced after a meeting in the offices of Mark Dyer Associates in Bristol, United Kingdom.

Summary: Although the public's concern for the environment does influence the development of policy and law it is ultimately governments who drive its promulgation. Law is the primary influence on the development of new technology with other factors: cost; scientific knowledge; and engineering methods and processes interacting to influencing the dynamics of development. He suggested the model illustrated in Figure 6.

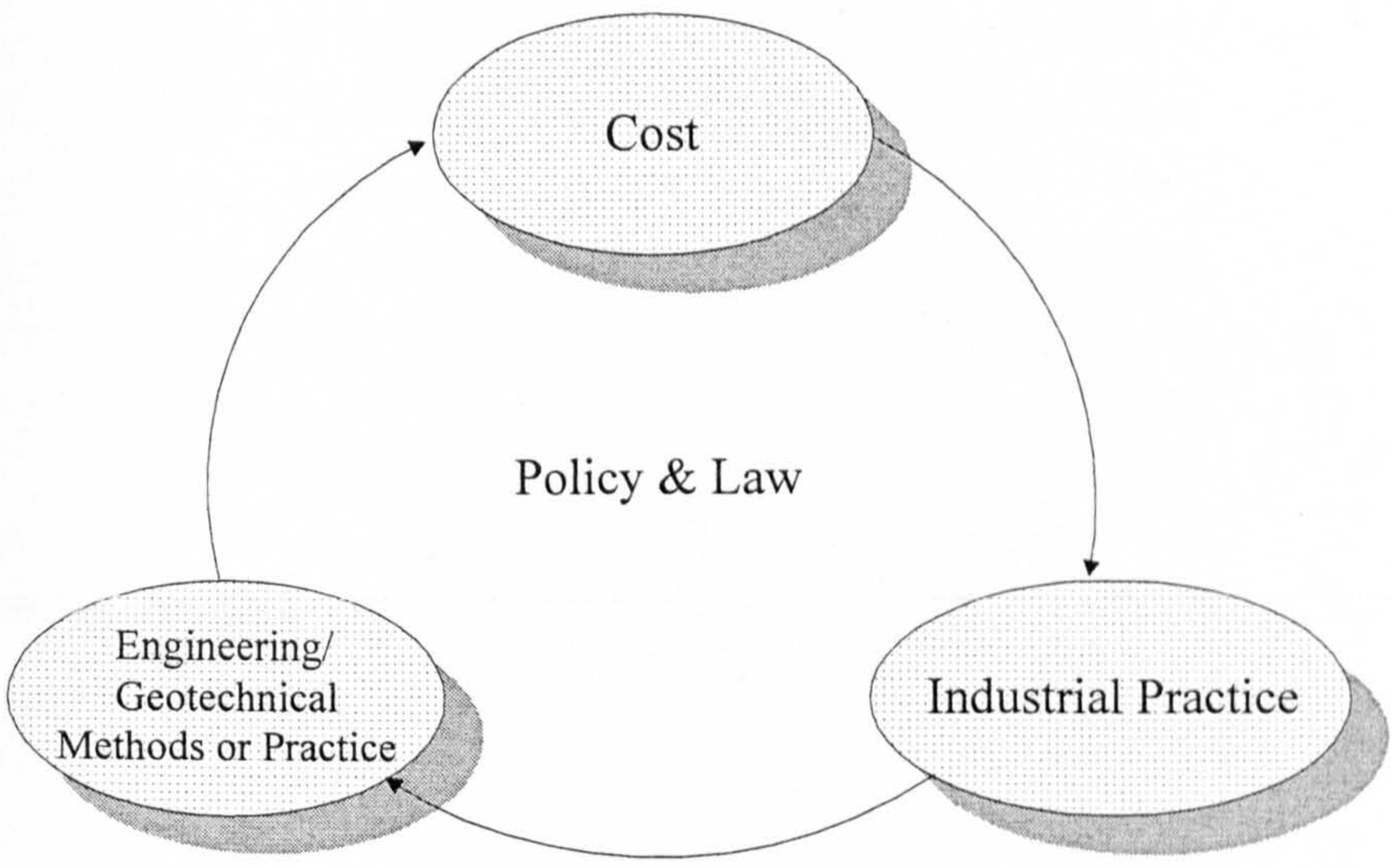

Figure 6: Dyer's Proposed Model for the Dynamics of Innovation.

Planning and zoning laws have prevented contaminated land from becoming a major problem in the United Kingdom. Conversely, environmental awareness in the Netherlands is due to their fragile environment and through necessity as opposed to a higher level of environmental concern. The thrust of new legislation is sensible as trigger levels are often rejected in favour of a more flexible risk based approaches.

The body of knowledge concerning land and groundwater contamination and its effect is inadequate to

attempt to develop treatment techniques. This leads to: expensive and impractical techniques; consultants with poor scientific understanding; and uncertainty that prevents the use and development treatment techniques. Promising techniques include: extensive technologies, active containment and bioremediation. i.e. techniques that depend upon an understanding of the ability of the soil to attenuate contamination. Funding the development of remedial techniques is not the job of the research councils. The research councils should carry out fundamental research, the DoE strategic and the EA applied. The United Kingdom is particularly strong in the area of generic or strategic work.

In response to the questionnaire, Mr Dyer stated a lack of basic scientific knowledge creates uncertainty in the market for remedial treatment and that this confusion remains unresolved in the United Kingdom. The developers of remedial techniques must invest in R&D to evaluate technologies. Policy is moving toward the transfer of liabilities to the purchasers of land. The global market for remediation will increase in size accompanied by more competition for rudimentary techniques. Successful techniques will be: bioremediation and natural processes. Threats to the development of treatment techniques in the United Kingdom are the low cost of landfill and the expense of contractors' designated plant.

4.2.9 Ian Burbidge and Cameron M. Scott	**Organisation:** Biotechna-Graesser Limited
Basis of the information: interview	**Location of full transcript:** Page 8-230

Context: Biotechna-Graesser Limited are a wholly owned subsidiary of Biotechna Environmental Limited (BEL). BEL operate in three areas: biotechnology; photosynthetic purification; and Graesser technologies. It is the last of these that has contaminated land applications. Biotechna-Graesser Limited license, lease and sell Graesser Contactors, a device commonly used in the chemicals industry to separate chemicals from waste for reuse. Recently Biotechna-Graesser have been working on applying the device to the remedial treatment of contaminated land. The following account was produced after a meeting with Mr Ian Burbidge and Mr Cameron Scott at their offices and laboratories in Dorking, Surrey, United Kingdom.

Summary: Recently, new American owners have instigated a number of changes in an attempt to make the contaminated land applications of the Graesser Contactor more competitive. The new management team have developed a questionnaire based system where a client's needs are analysed prior to any testing being carried out. This illustrates a cautious approach towards the development of the Graesser as a remedial technique- an approach that mirrors the uncertain nature of the remediation market. At present clients are relied upon to suggest applications. The demand for the Graesser is increasing where it forms a part of an integrated approach to remediation and development is an ongoing, albeit gradual, process.

As the Graesser already has an established market in the chemicals industry this is an area where the technique is particularly successful.

4.2.10 Gavin Costigan	**Organisation:** DTI and JEMU
Basis of the information: interview, with revisions by Gavin Costigan, and questionnaire	**Location of full transcript:** Page 8-232

Context: The DTI aims to help United Kingdom business compete successfully at home, in the rest of Europe, and throughout the world. To this end, amongst other objectives, the DTI: seeks to identify the needs of business; to ensure that environmental issues are taken into account in the development of its policies; and that these needs are taken into account by government. The Joint Environmental Markets Unit (JEMU) was established in 1992, jointly by the DTI and the DoE. JEMU's mission is to increase United Kingdom firms' awareness of markets for environmental goods and services. The following account was produced following an interview with Mr Gavin Costigan (DTI) and Mr Duncan Egerton (JEMU) at the DTI's offices in London, United Kingdom.

Summary: The process of internal consultation on contaminated land throws up numerous difficulties. Contaminated land policy has at its core the polluter pays principle, but designing laws which are fair and equitable is difficult, especially when trying to define who the polluter is or (more often) how much of the pollution he/she has caused.

In Gavin's personal opinion, even when environmental laws have undergone internal review and consultation they can still fail. e.g. it wasn't until the Section 143 Registers reached their final reading that the CBI and the Landowners Association realised their implications and lobbied against their introduction.

Uncertainty relating to environmental liability limits the redevelopment of brownfield sites. Although, a lot of this uncertainty will be removed when the provisions of Section 57 of the 1995 Act come into force.

In response to the questionnaire, Mr Costigan stated that the model in Figure 9 was somewhat simplistic as it could not deal with the complex decision making processes that a company attempting to deal with regulatory compliance would have to contend.

The Government must balance the priorities of different departments, and the priorities within departments. Within DTI, action taken to benefit one industry sector may disadvantage another. It is the Government's job to balance these factors fairly in such a way as to meet its overall objectives. Contaminated land policy in the United Kingdom is based upon the principles of *suitable for use* and the Polluter Pays. The Environment Act 1995 also formalises the common law liabilities already in existence.

4.2.11 Glenn Jones	**Organisation:** Biolytic
Basis of the information: interview	**Location of full transcript:** Page 8-235

Context: Biolytic offer a variety of services in the Biochemical field. Initially, the company treated discharge from oil tanker slops and tank washings. More recently, they have moved into the treatment of general liquid wastes, leachate, and the treatment of soil, silt and groundwater contaminated with organic contaminants and cyanides. The following account was produced following an interview with Mr Glenn Jones of Biolytic Systems Ltd at their offices in Washington, Tyne and Wear, United Kingdom.

Summary: Cost and the perceived ability for remedial technique to deliver precise results are major barriers to the development of treatment techniques. In addition, such techniques are commonly considered superfluous and are often the first element of a development to be cut when cost reductions are sought.

Specialist subcontractors providing remediation services have particular needs that clients and main contractors may not be able to manage effectively. Ideally, specialist subcontractors should act as consultants and have formalised links with consultants or clients. e.g. Biolytic have had to operate in conditions that adversely effect their remedial process because the main contractor did not understand the nature of the technique.

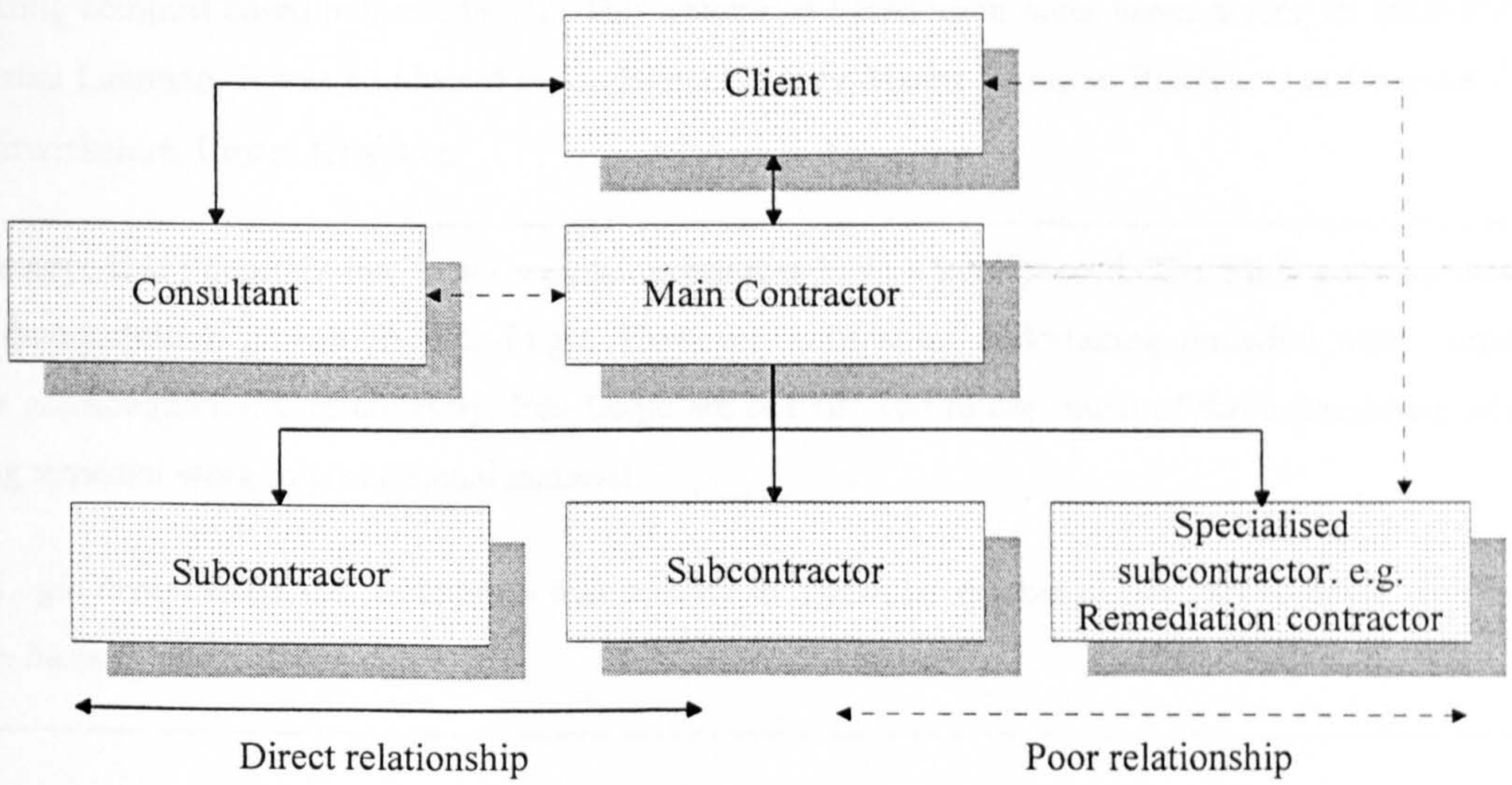

Figure 7: Consultant, Client, Contractor Relationship.

Figure 7 illustrates Mr Jones' perception of the consultant, client, contractor relationship.

Biolytic have considered developing a central processing facility. However, the recent decision on the Landfill Tax has made this idea uneconomical.

The lead times of many sources of research and development funding are in the order of two years. The uncertainty involved means Biolytic cannot afford the time to apply.

The Environment Agency will have an effect in about two years when they finally become established, although, the new regime will not be any stricter than the current regime as there will always be the emphasis on economic feasibility that will favour encapsulation techniques. The NRA have never been effective as the fines at their discretion are too low and they do not use their powers to full effect.

4.2.12 Brian Lassmann	**Organisation:** Eco-Logic
Basis of the information: interview and seminar	**Location of full transcript:** Page 8-237
Context: Eco-Environmental Services (United Kingdom) Ltd constituent companies include ECO-Composting Ltd, Patterson Exploration Ltd (PXS) and McKim and Creed. PXS have been developing bioremediation techniques in the United States for 8 years. Eco-Logic were formed after Mr Lassman contacted the Ministry of Defense with the suggestion that he could remediate hydrocarbon contaminated soil using compost based bioremediation. This account is based upon notes taken during an interview with Mr Brian Lassman. It was conducted at the Biotechnology Means Business Roadshow at Coombe Abbey in Warwickshire, United Kingdom.	
Summary: It is important that new remedial techniques have a track record. The MoD contract was used as a demonstration project for Eco-Logic. However, companies undertaking remedial work commonly desire confidentiality. Consequently, Eco-Logic are not allowed to use much of the information collected during remedial work in promotional material. Eco-Logic demonstrate that techniques that operate in particular market niches can compete with landfill on the basis of cost.	

4.2.13 Linda Fiedler	**Organisation:** USEPA TIO
Basis of the information: interview	**Location of full transcript:** Page 8-238

Context: The Technology Innovations Office (TIO) of the USEPA's Office of Solid Waste and Emergency Response (OSWER) is charged with the responsibility of preparing reports on the use of innovative treatment technology to remediate contaminated hazardous waste sites. They report on Superfund, RCRA and non-Superfund sites at which remedial technologies are used. Linda Fiedler prepares the annual status reports produced by the department. The following account was produced after a meeting in the Offices of the TIO in Washington D.C., United States.

Summary: The role of the TIO is informative, they provide data and guidance to Responsible Parties (RPs) that have been identified in Superfund Cleanups and other government departments such as the Department of Energy. RPs are responsible for approximately 75% of Superfund sites. However, it is difficult to secure funds from private firms to help develop remedial techniques.

The dynamic system illustrated in Figure 9 does not function smoothly as the demand for remedial techniques is not constant in the United States.

Public opinion effects the development of treatment techniques through the development of environmental policy and by its reaction to the technologies developed. e.g., in the latter case, public fear of the release of hazardous substances to the atmosphere has given *ex-situ* techniques a bad reputation.

There is a move away from the *preference for treatment* caveats introduced by SARA in 1986. Since this time: treatment systems; in-situ treatment; and finally natural attenuation, monitoring and active containment systems have been evaluated. This illustrates the move toward more cost effective treatments and the realisation that the levels of protection required in the United States are unrealistic. This view has been popularised in studies by organisations such as the General Accounting Office (GAO). Actions such as the Brownfield Action Agenda and Non-Time-Critical (NTC) operations are an illustration of a move towards a *suitable for use* approach and an attempt to solve problems pragmatically. Furthermore, this trend may encourage the use of remedial techniques but not necessarily high technology solutions.

Chemical companies are the principal market for remedial techniques. With the election of a Republican Congress there will be attempts to alter policy towards this pragmatic form of regulation.

4.2.14 John Martin	**Organisation:** USEPA
Basis of the information: interview	**Location of full transcript:** Page 8-240

Context: The Contamination and Remediation Branch of the USEPA are responsible for the verification of remedial technology at SITE demonstration projects. John Martin is Head of the Contamination and Remediation Branch. The following account was produced after a meeting at the National Risk Management Research Laboratory in Cincinnati, United States.

Summary: The SITE programme provides funding for the development of emerging technology and the verification of developing technology. When the new USEPA budget is agreed the funding for the development of emerging technology will be cut leaving only the verification role for the SITE programme. The legislation that is to replace SARA will place less of an emphasis on *preference for treatment* requirements and shall attempt to reduce the potential for litigation. However, in situations where there is a local community involved in remedial activity it will be difficult to move to more relaxed standards, although, it will be more straightforward in areas that are isolated. Regulators have been slow in introducing economic factors into the requirements that environmental targets be achieved. The reason for the present prevarication concerning Superfund reauthorisation is primarily due to it being a groundwater protection programme and because land contamination requires different solutions.

The uncertainty surrounding the reauthorisation of Superfund is damaging to the development of treatment techniques.

4.2.15 Michelle Simon	**Organisation:** USEPA
Basis of the information: interview	**Location of full transcript:** Page 8-242

Context: The Site Management Support Branch of the USEPA are responsible for site management, the provision of technical assistance, the design of remedial treatment, and the verification of remedial techniques on SITE demonstration projects. Michelle Simon specialises in the application of air sparging and Soil Vapour Extraction (SVE). The following account was produced after a meeting at the National Risk Management Research Laboratory in Cincinnati, United States.

Summary: Ms Simon stated that it can be difficult to persuade RPs to co-operate in SITE demonstrations as their primary goal is to clean-up land as quickly and efficiently as possible.

Commonly, SVE and bioventing techniques do not achieve tough Superfund standards. However, as requirements for clean-up are relaxing then these techniques are looking more useful. SVE and bioventing are used when natural attenuation is not feasible- as is the case in approximately 19% of Superfund cleanups. In addition, uncertainty still surrounds the use of these techniques. Consequently, basic understanding of the way techniques interact with contaminants and the environment is required.

SVE and bioventing techniques are increasingly in demand as they are: in-situ and less complicated that many ex-situ processes; low energy and effective when used against non-chlorinated organic compounds; and applicable for use on chlorinated compounds such as TCE (albeit with reduced efficiency). In order of preference natural attenuation will be used first then bioventing followed by SVE.

The remedial techniques most commonly used in the future will be natural attenuation and bioremediation. Low energy techniques will be preferred over high energy techniques.

4.2.16 Edwin Barth	Organisation: USEPA
Basis of the information: interview	**Location of full transcript:** Page 8-244

Context: Edwin Barth, P.E. is technical contact for Brownfields activities at the National Risk Management Research Laboratory. He is a member of the Site Management Support Branch, providing technical assistance to USEPA's Regional Office on abandoned sites. He is a national expert in solidification/stabilisation technology and was one of the authors on the American Academy of Environmental Engineers Monograph Series on Waste Treatment Technologies. The following account was produced after a meeting at the National Risk Management Research Laboratory in Cincinnati, United States.

Summary: The Brownfields initiative was introduced because the Superfund system was considered too rigid. High technology solutions will be used less and mostly on the complex, higher risk sites which require special treatment.

RCRA is moving towards Risk Based Corrective Action that recognises that natural attenuation is a valid remedial option. Superfund National Priority sites will increasingly be contained and remediated by natural attenuation. When Superfund is reauthorised it will no longer contain a *preference for treatment*. This is partly due to the influence of the Republican congress who are sympathetic toward industry. The new legislation will have a technical and practicability waver that allows difficult sites to be contained on the grounds that remediation is not feasible. However, there will not be an outcry against these measures as the public are aware that the Superfund programme has been ineffective. The Brownfield Action Agenda will succeed where Superfund failed as the public are more willing to accept the low key treatments it will involve and the fact that these create comparatively less air pollution and have less effect upon property values.

4.2.17 Round Table Discussion	**Organisation:** USEPA
Basis of the information: discussion	**Location of full transcript:** Page 8-245

Context: The Land Remediation and Pollution Control Division (LRPCD) of the USEPA conduct research and development into remedial techniques in partnership with the private sector. The techniques they develop are tested at SITE demonstrations. The following account was produced after a round table meeting with Dr Jim Ryan, Dr Taras Bryndzia, Dr Wendy Davis-Hoover and Dr Dave Carson of the USEPA LRPCD at the Centre Hill Research Laboratory in Cincinnati, United States.

Summary: Three routes were identified for the development of new remedial techniques. These were: scientists who see the potential for novel technical applications of technology; businessmen who see the potential value of technology crossovers; and companies threatened with environmental liability who develop solutions to their own problems and then market them commercially. All developers face the barrier of attempting to develop techniques on a large scale.

Public perception plays an important role in the development of treatment techniques. Innovation is stimulated by policy which is driven by the public perception of risk which in turn drives the type of research that is carried out. In addition, the public perception of risk is also a major influence on the level of remedial action taken at a site, often more so than risks calculated by any environmental decision making process.

When Superfund was promulgated the stock of contaminated land and groundwater in the United States was underestimated, this error was compounded by the fact that no evaluation of the legislation occurred until public perception required its revision. Consequently, the Superfund programme is reactive and standards are ultimately driven by technological capability.

The price of real estate in California and parts of the east coast means that new techniques are becoming cost effective. However, the liability regime in the United States is still a limiting factor.

Private/public partnerships such as the Research Technology Developers Forum, an initiative to encourage co-operation between the USEPA and chemical companies, are unusual in the United States due to the adversarial regulatory regime.

4.2.18 Ed Bates	**Organisation:** USEPA
Basis of the information: interview	**Location of full transcript:** Page 8-247

Context: Ed Bates is a Site Manager for the Site Management Support Branch of the USEPA (see Michelle Simon, Section 4.2.15). He specialises in stabilisation and solidification techniques and wetlands. The following account was produced after a meeting at the National Risk Management Research Laboratory in Cincinnati, United States.

Summary: The developers of treatment techniques are commonly small companies. These companies do not realise the problems associated with developing remedial techniques. Consequently, they find it difficult to develop techniques commercially.

The public sector can developed remedial technology because it is not hampered by the problems of developing techniques at field and commercial scale. Wetlands (reedbeds) techniques were developed in the public sector. However, such techniques can be unrealistically expensive.

When private organisations are dealing with their own problems they are more willing to risk the use of treatment techniques. However, information gathered by private organisations is not in the public domain. Consequently, the developers of the techniques used in these situations are denied publicity.

The influence of public opinion can be damaging for treatment techniques. e.g. although incineration can be used successfully to destroy contamination in soils, public opinion limits its use. However, public interest and industrial lobby groups balance each other's efforts. The overall effect is one of balance- President Reagan's attempt to remove the burden of environmental regulation is an example.

The different regulatory philosophies of RCRA and CERCLA are the result of their creation by separate Congressional Acts. Consequently, regulation can be inconsistent and the developers of new remedial techniques face uncertainty. These problems are overcome in the trial stages of development by the Superfund Treatability Exemption but not when full scale field tests are required.

Public opinion influences policy in phases. The various environmental agencies have their mandates altered at varying rates. Consequently, CERCLA and RCRA do not always work in harmony.

4.2.19 Kandi Brown	**Organisation:** IT Corporation (United States)
Basis of the information: interview	**Location of full transcript:** Page 8-249

Context: IT Corporation is a large United States company that specialises in the development of environmental technologies. Kandi Brown is a project Engineer with IT. She has worked with the USEPA on a number of projects developing novel remedial techniques at SITE schemes. She is currently working on the development of a slurry reactor for the removal of PAHs from soil as a part of the SITE Emerging Technology Programme. The following account was produced after a telephone conference with Kandi Brown of IT Corporation in California and Brunilda Davila of the USEPA in Cincinnati, United States.

Summary: The SITE scheme plays an important role in the development of treatment techniques in the United States: it allows the collection of data; relieves uncertainty; and facilitates the full scale development of remedial techniques. Strong regulation means that clients wish to appear environmentally aware. Consequently, SITE demonstrations can be arranged; although, many clients wish to retain confidentiality. Federal regulators can allow confidentiality but state regulators may not. In addition, clients are uncomfortable being the first to use a novel technique. Therefore, small companies often come to IT to request help in field testing and developing novel techniques.

Passive, in-situ and natural attenuation techniques are becoming popular. These techniques have been developed recently on the west coast of America at military bases. The move from high to low tech solutions was not foreseen in the 1980s but the techniques are the most cost effective.

The public are becoming increasingly knowledgeable about contaminated land issues. However, although IT attempt to educate both the public and regulators when using remedial techniques it is inevitable that the more high profile the site the more education and assurances have to be given.

It is important to involve regulators from an early stage in a project as this can mean a reduction in project time and cost. Communication is vital in any project.

4.2.20 Neil Davies	**Organisation:** Geosyntec (United States)
Basis of the information: interview	**Location of full transcript:** Page 8-251

Context: Geosyntec are specialist consultants in environmental geotechnology. They place a particular emphasis on the application of geosynthetics to geotechnical problems. Neil Davies is a Senior Project Engineer for Geosyntec in the United States, although, he originally worked in the British water industry. He has been involved in the remedial treatment of a number of Superfund sites. The following account was produced after a meeting in the offices of Geosyntec in Atlanta Georgia, United States.

Summary: Both RCRA and CERCLA regulations are applicable at Superfund sites, USEPA managers decide which regulations are required. This will usually be the most stringent. This illustrates the lack of clarity that may exist around a Superfund project. Although, increasingly regulators are taking a more reasonable approach and granting wavers on certain regulations. This change in attitude is further illustrated by the way cost is incorporated into the Superfund process. i.e. cost is now used to delineate between potential techniques, although, the protection of the environment, or the "threshold criterion", is still a more important criteria than cost on Superfund sites.

In Louisville Kentucky a site near a landfill was contaminated by illegally dumped waste. Eight tenders were received to remediate the site. The more advanced treatment techniques were approximately 80-100% more expensive than incineration, despite an impression that the more treatment techniques would be quoted at cheaper process. However, the operators' relative lack of experience meant that they were unable to quote prices with any certainty and consequently their tenders were high.

It would be more realistic to remediate sites to 90% of present requirements. In such cases clean-ups would cost 10% of a normal Superfund site. e.g. in Louisville, the final remedial treatment of contaminated soil took two years and $20 million. However, regulators are attempting to address this problem. NTC clean-ups and Superfund Accelerated Cleanup Model (SACM) procedures remove unnecessary regulatory procedures and reduce the time and cost of remediation. However, such state run programmes can fall foul of national regulations.

Superfund is driven by the protection of groundwater. Groundwater is considered more important in the United States than in the United Kingdom. In addition, the American public is more aware of groundwater problems.

4.2.21 Randy Sullivan	**Organisation:** Golders (United States)
Basis of the information: interview	**Location of full transcript:** Page 8-253

Context: Golder Associates is a major geotechnical consultancy that operates extensively in the United States and Europe. Randy Sullivan in the head of Golder's office in Atlanta. The following account was produced after a meeting in the offices of Golder Associates in Atlanta Georgia, United States.

Summary: Ultimately, Superfund is a federal programme and this contributes to its adversarial nature, rigidity, and restrictiveness. In contrast, the state regulation of RCRA is less confrontational and offers more realistic standards based on waste streams rather than general levels of risk.

Legislation in the United States tends to be reactive. Furthermore, Superfund regulation can discourage PRPs from undergoing voluntary remedial treatment. However, a realisation of the potential cost of remediating DOE and DOD sites has prompted Congress to study the problems caused by contaminated land regulation. e.g. at voluntary clean-ups certain aspects of the Superfund process can be foregone. Also, brownfield developments are becoming more popular, particularly as the USEPA is keen to emphasise that most contaminated sites are of the less regulated brownfield category rather than Superfund. PRPs accept that they must remediate their contaminated sites but there is also an increasing need to recycle derelict land.

High profile polluters such as chemical companies tend to opt to clean-up their land internally because of a fear of liability and adverse publicity. However, the majority of the contaminated land work is driven by regulation and the current stalling of the Superfund programme is having an adverse effect on the market for remediation. In addition, the inability of vendors of remedial techniques to offer fixed prices for their techniques creates uncertainty.

The public have a poor perception of risk. Factors such as: the value of land; the risks associated with treatment and encapsulation; and the differences between short and long term risk all colour public opinion.

The client/consultant/contractor relationship is difficult. General contractors and clients may not understand the complex earthworks involved with remedial techniques. However, as the market for environmental consultancy in the United States has matured, with larger firms dominating the market, understanding is growing. There is a market for treatment techniques in the United States but it is falling off slightly. The work available is for RCRA, Superfund and brownfield development.

4.2.22 Dr Stephan Jefferis	**Organisation:** Golders (United Kingdom)
Basis of the information: interview	**Location of full transcript:** Page 8-256

Context: The following account was produced after a meeting with Dr Stephan Jefferis of Golder Associates in their offices in Maidenhead, United Kingdom.

Summary: Section 57 of the Environment Act 1995 aims to enable a civil law framework with statutory controls. However, common law will remain an important aspect of the regulation of environmental pollution because statutory liability in the United Kingdom is only geared towards the prevention of *serious* threats to health and the environment. Under the Environment Act 1995 contaminated land is relatively narrowly defined.

Clients tend to accept cheaper quotes for remedial work. However, this is a false economy as the price of remedial treatment is commonly higher than expected and contractors who give cheaper quotes may not be able to achieve the desired results.

The three environmental media are regulated for different reasons. As air pathways usually dominate the mobility of contaminants air is regulated by risk, water is regulated because it is a resource and land is ignored as it poses neither a risk nor is it a resource. This complexity is reflected in the difficulties of regulating new techniques. At present contaminant concentration is the driver for remedial treatment but quantity defines contamination. However, the regulation of active containment will probably be to drinking water standards because this is how water is regulated, i.e. as a resource.

Compliance costs of the Landfill Tax will actually be more than the tax level due to administrative costs. Dr Jefferis suggested a cost of £14-21 for a tax level of £7.

Treatment techniques have the ability to generate their own markets. New techniques making the cost efficient clean-up of complex contaminated sites feasible.

4.2.23 Malcolm Lowe	**Organisation:** DoE, Contaminated Land Office
Basis of the information: seminar	**Location of full transcript:** Page 8-258

Context: Malcolm Lowe recently replaced Dr Judith Denner as the head of the DoE's Contaminated Land Office. He has played a major role in drafting the contaminated land provisions in Section 57 of the Environment Act 1995 and the guidance that is to be issued to local authorities on the definition of contaminated land. This account is based upon two seminars: a one day seminar on interpreting the Draft Guidance on Contaminated Land organised by the University of Cambridge Programme for Industry in Cambridge, United Kingdom; and a meeting of the Environmental Industries Commission (EIC) Contaminated Land Working Group at the offices of Bristow, Cooke and Carpmael, London, United Kingdom.

Summary: The failure of the Section 143 Registers made clarification an imperative for any future legislation- hence the large amount of consultation that has been undertaken on Section 57 of the Environment Act 1995.

The intention of the new regime is to: improve the clarity of the existing regime in terms of the range of controls (this is the role of the statutory guidance and the EA); to clarify ambiguous definitions (such as the definition of harm in the present regulations on statutory nuisance); and to reinforce the concept of *suitable for use.*

The *suitable for use* regime focuses on realism. "Hard policy choices" have to be made because there is not enough money or knowledge to deal with the problem of contaminated land immediately. Contaminated land is defined in relation to current land use and problems are addressed when land use changes. The majority of derelict and contaminated land will be cleaned up through the process of redevelopment

The Guidance and the Act are an attempt to re-affirm the statutory duties already in place. The deregulatory approach is designed to avoid litigation, i.e. enforcement is at a long chain of action that ends with criminal measures. This is in recognition of the problems that will be caused if regulators have to go to court to resolve problems.

The ICRCL guidelines are to be replaced by CLEA guidance, although, consultants will have the freedom to assess risk in whatever manner they choose provided they can justify their actions

4.2.24 Prof Malcolm Grant	**Organisation:** University of Cambridge
Basis of the information: seminar	**Location of full transcript:** Page 8-260

Context: The Department of Land Economy at the University of Cambridge was commissioned by the DoE to furnish advice on the design of the Guidance on the Definition of Contaminated Land, they also participated in the drafting of the compliance cost assessment for these provisions. Professor Malcolm Grant is Head of the Department. This account is based upon a seminar on interpreting the Draft Guidance on Contaminated Land organised by the University of Cambridge Programme for Industry in Cambridge, United Kingdom.

Summary: The position of the DoE is paradoxical when it states that the new contaminated land provisions can firstly, introduce a system for the regulation and remedial treatment of contaminated land, and secondly, be easily and cheaply introduced due to the fact that the provisions contain no new statutory duties.

Section 57 of the Environment Act 1995 is strict, retrospective and has the potential to include a wide range of potential polluters that are narrowed down on a sequential and chronological basis with the most recent offenders being liable. The exclusion provisions within the Act introduce a form of joint and several liability as if a site involves an orphan share of liability, for which there is no money to pay, then local authorities will attempt to apportion this liability on the Appropriate Persons (AP) identified under the Act. Consequently, in sites where there are orphan shares of liability remediation orders may lead to litigation as to the exact apportionment.

Land use planning plays an important role in the *suitable for use* approach. Planners and local authorities have dual powers to develop strategic plans under Planning Policy Guidance (PPG) documents numbers 2 and 23. However, there is a funding gap between the redevelopment process and the orphan sites. Planning gain could be used to bridge this gap and solve the problems of brownfield development. i.e. to encourage the market for remediation by underpinning it with the planning process.

4.2.25 Stephen Tromans	**Organisation:** Simmons and Simmons
Basis of the information: questionnaire	**Location of full transcript:** Page 8-261

Context: Stephen Tromans is Head of the Environmental Law Department at Simmons and Simmons, Chairman of the United Kingdom Environmental Law Association and is co-author of Contaminated Land (Tromans and Turral-Clarke 1994), one of the most complete reference works that has been written on the subject of contaminated land liability in the United Kingdom. The following account is based upon a questionnaire response.

Summary: In response to the questionnaire Mr Tromans suggested the figures in the questionnaire were unhelpful because the items placed "at the centre" were not shown to be causally linked with the other factors, and therefore appeared both more and less important than them. The model illustrated in Figure 8 suggests something is needed to "push" the development of new techniques.

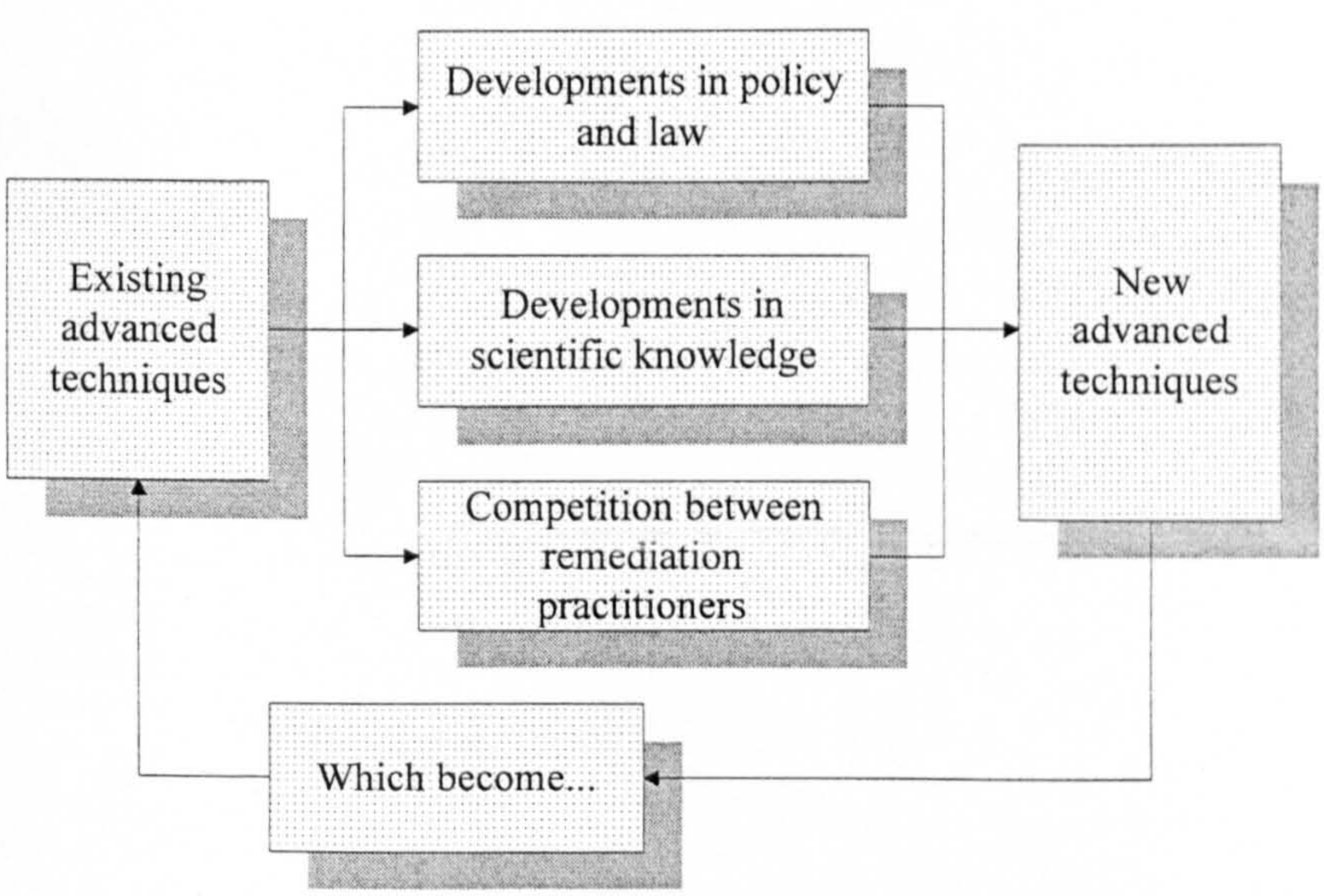

Figure 8: Troman's Model of the Development of Treatment Techniques

Uncertainty as to whether a particular level of remediation is required by law, and if so whether it will be enforced and the level of penalty for non-compliance, could discourage land owners from investing in remediation to that level. This encourages reliance on existing remedial measures even where liabilities may never materialise.

Experienced can be gained by introducing a technique in a jurisdiction where policy and law is most favourable to their use, or by cutting prices initially in order to attract and carry out enough contracts to have a credible track record.

The state owes a duty to the public to ensure adequate protection of the environment, which includes, in a market system, removing externalities.

Contaminated land policy is moving very much towards risk assessment. At this stage it is impossible to say what the standard of acceptable risk (the other side of the "significant harm" coin) will be. Also, towards ensuring so far as possible that remediation occurs as a pre-condition to development, when there is a private pocket to fund it.

4.2.26 Jim Begley	**Organisation:** AEA Technology
Basis of the information: questionnaire	**Location of full transcript:** Page 8-263

Context: AEA Technology are an international science and engineering services business who specialise in the exploitation of new technologies as marketable products. The AEA National Environmental Technology Centre combines the resources of AEA Technology and the Warren Springs Laboratory where much of the work carried out on the verification of advance remedial techniques in the United Kingdom has taken place. Jim Begley has been involved in site remediation for over 11 years, 10 of which were spent in the United States. The following account is based upon a questionnaire return.

Summary: Figure 6 (Dyer's Proposed Model for the Dynamics of Innovation.) with the addition of the profit motive of the entrepreneur illustrates the development of remedial techniques. A key aspect is the cost and availability of low-tech options like landfill. If low cost landfill is unavailable then a more innovative technical option is cost effective.

Uncertainty occurs when the following factors cannot be demonstrated or quantified: cost effectiveness; technical effectiveness (ability to reach clean end point); implementability; potential side effects; and residual risk. This is best resolved through private/public partnerships. e.g. military bases in the United States have been used as testing grounds. The problem holder is big enough to absorb a failure without risk and see a potential cost saving benefit worth the risk. Without the benefit of a public demonstration site it would be best to "start small", develop a track record and publicise the results.

Contaminated land policy is moving slowly forward in the United Kingdom and has leveled out in the United States. The state should provide adequate regulation to protect public health and the environment for all. Beyond that, the state can improve the environment and improve the economy by providing public/private support to developers.

Global markets for treatment techniques differ regionally. There is a bigger market for basic technology, i.e. carbon treatment for water and air, than for more innovative methods. As developing countries move from clean water, to clean air and finally to contaminated land issues, innovative technology markets will grow. Successful remedial techniques will be: competitive priced; offer assured end points; and have the best timelines to completion. They shall have: low levels of uncertainty; fit within a package of kit and/or service; and strong regulatory support, i.e. destroy contaminants or bind it permanently with minimal associated risks. The right timing is the best opportunity and the biggest threat facing the vendors and developers of treatment techniques.

4.2.27 Professor Raymond N. Yong	Organisation: McGill and Cardiff Universities
Basis of the information: Personal communication	

Summary: Environmental policy generates the requirement to remediate contaminated land. However, policies are based upon vested interests, be they environmental, social or business based- furthermore, governments receive advice from several areas and these are all subject to diverse influence. Professor Yong emphasised the influence of vested interests in the contaminated land industry. He made the point that in all the research questions asked by this research the influence of vested interests was evident. The creation of contaminated land policy is in reaction to and an attempt to balance a number of vested interests. Similarly, public opinion can influence the development of treatment techniques through the vested interests which are pressure groups and the media. Furthermore, the effects of these vested interests is not always for the best. The example of incineration as a remedial technique being a good example. This technique is well established in Austria and Germany but has experienced difficulties in the UK due to problems with fugitive emissions that have long since been addressed in modern facilities.

Policies are an attempt, built upon the diverse advice from a variety of conflicting interests, to provide solutions via legislative requirements and , in the case of contaminated land, technical conformance with specific requirements. However, in the contaminated land industry a consensus has yet to be reached concerning what levels of risk are acceptable, particularly as we have to pay to reduce these risks. Documentation such as the CIRIA guidance is a start but there is still a long way to go in respect to this.

4.3 CASE STUDIES

4.3.1 Case Study #1: Remediation of Light Industrial Unit in SE England

Developer A is proposing to redevelop the existing Property B in a joint venture with Owner C for new warehousing on a different layout with improved vehicle access and car parking. The site currently contains a 1960's low-rise warehouse complex in rather a poor state of repair, including some flying props supporting one rear corner of the building.

STATS Geotechnical Ltd has carried out a site investigation in a total of four phases which has included a Phase 1 geotechnical and geoenvironmental desk study and site reconnaissance and Phases 2, 3 and 4 intrusive ground investigations comprising boreholes, trial pits and associated sampling, monitoring and testing.

The historical information consulted indicates that the site was originally developed over low-lying water meadows after the whole of the surrounding industrial area had been built up with up to around 2m/3m of fill material.

The ground conditions beneath the site, identified from the exploratory holes, comprise:

- 0.7m to 4.0m of made ground, generally consisting of thin granular fills over clay fills;
- up to 3.5m of fine alluvium consisting of interbedded soft and very soft silty clays and organic clays and bands of soft or firm peat;
- 1.7m to 3.1m of medium dense sands and gravels;
- London Clay from depths of between 4.6m to 7.1m below ground level, consisting of firm to stiff increasing to stiff to very stiff slightly sandy very silty clay;
- Groundwater standing at between about 1m and 2.25m below ground level.

The ground/groundwater to the rear and beneath much of the existing building is relatively heavily contaminated with hydrocarbons (diesel mainly) over an area of the order of 3000 to 4000 m^2. The main contaminant plume is found between depths of around typically 1.5m to 2.5m, but locally down to at least 4m. The hydrocarbons appear to be concentrated in the organic-rich alluvium and lower layers of made ground. The maximum recorded total petroleum hydrocarbon concentration is just over 7000 mg/kg in soils. The effected area extends both beyond the rear site boundary and onto the adjacent property but in

both cases this seems to be at concentrations much less than in the worst effected area by the former tank and beneath the rear centre of the existing building.

It was concluded that these concentrations of contamination were unacceptable and that remediation was required. One of the primary motivations for this decision was the value of the site to the Property Developer A, who was concerned with the potential for future liability relating to the property and the difficulties which would be involved in its sale in a contaminated state.

Assessment of options

The cost of removing the contaminated soil and its disposal at a licensed facility was estimated at £500,000. This was based upon a figure of £35/tonne for disposal based upon the need to remove 8000m^3. The fact that the contamination at this site is predominantly organic made it particularly suited to biological treatment techniques and their use was recommended.

The use of active containment techniques were discounted by the Property Developer A due to the need to sell part of the site following remediation and development.

The geoenvironmental report on Property B produced by STATS Geotechnical in July 1997 was sent to five remediation contractors: Companies V through Z.

A preliminary assessment of their ability to remediate the site was requested and specific reference was made to: timescales; costs; and details of proven experience with such sites.

All of these organisations responded and a summary of their submissions is provided in Table 16. Four detailed submissions were received including two proposing in-situ techniques and two proposing ex-situ techniques.

In Situ Techniques

Generally, the in-situ techniques, suggested by Company W and Company V, offered the advantage that the existing structure would not require demolition prior to the works taking place. The techniques are able to operate through holes, drilled about 1.5-2m centres, in the floor of the building. Furthermore, the predicted costs of these techniques were significantly less those of the ex-situ techniques, see Table 16.

However, we advised caution with respect to the use of in-situ techniques due to the high clay content of the soil and the presence of peat. Low permeability clay soils can markedly reduce the effectiveness of in-situ techniques as can the presence of peat that may reduce the availability of any contamination for treatment. Both these contractors suggested these problems had been addressed in their assessments and both are willing to offer guarantees on cost and clean up levels, but not on completion time.

Ex Situ Techniques

The disadvantage of the ex-situ techniques were cost and the necessity for the structure to be demolished. However, the ex-situ solutions offer the advantage of speed. For example, the time estimate by Company Z included mobilisation, reporting and time for negotiation with the EA. Together, these additional activities could add up to four months to the total project time. This suggested the actual time Company Z would need to carry out the site work was about 2-4 months, a similar time to that suggested by Company Y. In contrast, these factors could increase the total project time for in-situ remediation to 11-13 or 9-15 months for Company V and Company W respectively. Again, the ex-situ contractors were willing to offer guarantees on cost and clean up levels.

Costs

The range of costs for the project, as shown in Table 16, was initially predicted to be between £50,000 and £140,000. We did not anticipate however that Company W would be able to achieve the £50,000 minimum limit on this site. The differences in costs were compared with the differences in time needed to achieve the end clean up required.

We considered both in-situ and ex-situ techniques to offer advantages and disadvantages. Specifically, in-situ remediation was considered viable if the criteria for remediation was restricted to approximately 1000mg/kg. However, we had doubts as to whether these techniques could achieve the target of 200mg/kg within a reasonable period of time. The ex-situ techniques offered the advantage of speed and the ability to reduce the contamination levels to the lower level albeit at a higher cost.

Recommendations

STATS-Geotechnical recommended further detailed technical discussions with the various contractors and site visits to see the techniques in action. Indeed, all the contractors expressed a willingness to be allowed to demonstrate their techniques in the field. The purpose of this exercise was to allow some of the uncertainties with the performance of the techniques to be clarified, particularly with relation to the ability of the in-situ techniques to meet their claims.

During discussions with Property Developer A and Owner C it became clear that time constraints played an important role in the redevelopment and remediation programme. These time constraints related to the need to complete the demolition, remediation and construction of a new warehouse within approximately seven months. Consequently, this precluded all the techniques apart from those offered by Company Y and Company Z. The in-situ techniques were discounted immediately due to this time constraint and Company Z stated they could not meet this criteria with confidence. This later point related to the method of ex-situ bioremediation employed. Although both Company Y and Company Z proposed the use static piles to

remediate the soils, Company Y proposed the more active treatment, involving more mixing and treatment of the soil, which would enable the soils to treated faster.

Developer A and Owner C have now provisionally agreed to the remediation strategy proposed by Company Y. However, the decision to undertake the work is being delayed because Owner C is undergoing negotiations with his partners in relation to the redevelopment of the site.

After detailed planning the estimated cost of the remediation rose to £200,000. This was due to the Owners requirement for office space which necessitates that the remediation be conducted in two phases, the second phase of remediation not stating until new office units could be constructed on the first phase. The effect of this decision on the predicted costs are twofold: firstly, the mobilisation of plant is duplicated; and secondly, by requiring a two phase remediation, the surface area available for the process is reduced with the result that two process batches are required with the resultant increase in costs.

Table 16: Summary of Remediation Contractors Proposals

Company	Technique	Time	Cost	Relevant Experience	Comments
A	In-situ bio-remediation	8-10 Months	£80,000	Experience of in-situ remediation of oil spillage	Does not require demolition Plant and civil costs extra Guarantee on cost and clean up level not time
B	SVE and air sparging	6-12 Months	£50-£80,000	Use of SVE and sparging at filling stations Currently treating organic solvent spill with SVE and sparging in Harlow	Does not require demolition Guarantee on cost and clean up not time
C	-	-	-	-	No specific information provided
D	Ex-situ bio-remediation	2 Months (process only)	£140,000	Remediation of 5,000m^3 of oil contaminated soil in 1 month	Time does not include negotiation with EA (1-4 Months) and mobilisation and reporting (1 Month) Requires demolition of existing structure Guarantee on cost and clean up not time
E	Ex-situ bio-remediation	5-9 Months	£137,000	Remediation of diesel and kerosene in-situ Wide range of remediation experience	Requires demolition of existing structure Possibility of Guarantee on cost and clean up level

4.3.2 Case Study #2: Remediation of Former Fuel Depot, SE England.

It is proposed to develop the site of a former fuel storage depot for residential housing comprising two-storey residential housing, gardens and car parking.

On the instructions of Developer D, STATS Geotechnical Ltd carried out a site investigation to help provide information on the ground conditions in relation to the proposed development. The site has historically been occupied by a petroleum storage depot, but is currently derelict and partially remediated to the standard of industrial end-use.

The ground conditions beneath the site, identified from the exploratory boreholes, comprise up to 2.5m of granular made ground. This overlies an impersistent layer of Fluvial Sand and Gravel, with London Clay beneath. Groundwater is present within the Made Ground and underlying sand and gravel. Groundwater flow is predominantly to the south east, dictated in part by artificial drainage measures and the overall dip on the London Clay interface.

With regards to ground contamination there is evidence of fairly extensive contamination by petroleum hydrocarbons, with about two-thirds of the site affected. In addition there is evidence of contamination with respect to metals in the north west corner of the site, although this may be attributed to on-site migration of contamination from the neighbouring plating works.

The chemical analysis of groundwaters suggests relatively widespread contamination with respect to petroleum hydrocarbons and ammoniacal nitrogen. There is also local minor contamination with respect to PAH, cyanide and metals.

The monitoring of soil gases has indicated the presence of elevated concentrations of carbon dioxide beneath the site in a number of locations and elevated methane at one location on the north eastern site boundary.

We consider the potential for off-site migration of contamination in both the gaseous and aqueous phase to be high. There is therefore an issue of third party liability associated with the site.

With regards to the proposed development, the degree and extent of the existing contamination was considered to represent a significant risk to human health. Therefore, it was concluded that if the proposed development was to proceed, some form of remediation would be required to remove the hazards present on site or to reduce the risks of exposure to these hazards by addressing the pathways that could link the contaminant source to targets. It was estimated that approximately 16,200 m^3 of material requires remediation.

A number of remediation options were considered and these include:

- Removal of contaminants off-site and replenishment of void;
- Treatment of contaminants ex-situ; and
- Treatment of contaminants, in-situ.

These options were reviewed and the use of in-situ remediation involving soil and groundwater vacuum extraction combined with warm air-sparging was considered the most suitable remedial method. This was because ex-situ biological treatments were discounted due to the lack of space on site for treatment. This lack of space implied that the number of treatment batches would be high with the resultant increase in cost and time this would entail. Costs estimates for ex-situ biological treatment were in the region of £450,000 to £500,000 for the remediation of 16,200m^3 of soil. Time estimates were in the region of 18 months due to the need to treat the soil in four or five batches.

However, in-situ treatment was rejected by the Developer D in favour of the removal of the contaminated material to landfill. The cost for this remedial option, based upon the need to remove 16,200m^3 of soil at an average of transportation and disposal cost of £35/tonne is estimated at £965,000. The reason for this decision was that the Developer D desired the total removal of the contamination from the site in order to remove the possibility of third party liability. Furthermore, the time frame in which the developer wished to redevelop the site did not allow for the use of in-situ techniques that were estimated to require 12 months to complete the remediation.

4.3.3 Case Study #3: Remediation of Light Industrial Site, London

This site was situated in West London. The site had a history of a variety of commercial developments between the 1930s and the present day. The proposal was to redevelop the site for residential purposes. A detailed investigation was carried out which generated a significant amount of both geotechnical and environmental data.

No local sensitive controlled ground or surface water targets were present in the area.

The physical conditions beneath the site comprised made ground, mostly a thin layer with areas beneath one of the buildings where a more significant thickness was present (1m+), overlying alluvial clay over London Clay. The made ground consisted of either black ash, where the thickness was limited, or brick rubble with some ash where the thickness was more substantial.

Perched groundwater was identified in some locations. Tests revealed that the water was free of significant contamination.

The intrusive investigation identified that contamination was present within the made ground. The contamination was limited to phytotoxic metals and lead and a significant correlation between the black ash and the contamination was apparent. The underlying alluvial clay was found to be contaminated with respect to arsenic, which was marginally above the ICRCL Threshold Trigger Concentration (TTC) for private gardens. This "contamination" was attributed to natural occurrence.

On the basis of *inter alia*: the groundwater results, the lack of mobilisation of the metals, the natural origin of the "contamination" within the alluvial clays, the lack of off-site targets for the contamination and the only slightly elevated metal concentrations led to the conclusion that the risks to health and the environment were low and not significant. The proposed remediation for the site was to remove the ashy made ground and in the rear gardens place 0.5m of clean cover.

The reaction of the housing developer to these proposals were that these remedial measures were not adequate. They required the site to cleaned to a level below ICRCL TTC, despite the low risks involved. The reason for this was their solicitors advised that the site should in no way be considered "contaminated". Consequently, the site was not remediated as this addition work would have made the redevelopment uneconomical.

4.3.4 Case Study #4: Remediation of Former Psychiatric Hospital, SE England

This site is to be redeveloped by a property developer for residential use. Preliminary site investigations found the ground level of the site to have been raised by the importation of fill material from unknown sources. Contamination was expected on the site and it was found respect to PAH, at considerably elevated concentrations, and minor heavy metal contamination. Although the use of treatment techniques was suggested to the developer with respect to the biological treatment of the PAH contamination, this option was discounted due to the need to redevelop this site quickly. Further perceived problems were that because some of the contaminated soil on site may have qualified as "special waste", according to local authority classifications, this may have necessitated detailed approval from the HSE and EA prior to remediation. Furthermore, the developer was not willing to consider:

- altering the phased development of the site from that already planned to accommodate the treatment of the contaminated soils, or

- the possibility of changing the layout of the proposed development to enable more of the less significantly contaminated material to be encapsulated.

Consequently, it was decided that the PAH contaminated material was to be disposed of at a licensed landfill. However, after an assessment of the risks associated with the heavy metal contamination on site had been conducted, it was suggested that this material should be removed from the near surface in areas that were to occupied by gardens and that this material be used as fill at depth in the voids created by the excavation of the PAH contamination. It was recognised that after the heavy metal contaminated soil was excavated it could be classified as waste and therefore this action could require a waste management license under the Waste Management Licensing Regulations- a decision which would preclude this option. Consequently, negotiations with the Environment Agency were held to discuss the classification of the material. It was argued that the soils were *suitable for use* as a fill material in this specific case and therefore could be exempt from waste management licensing regulations based upon the following justifications:

1. The material was to be encapsulated beneath a cover of 0.6m of clean fill material to prevent the direct contact or ingestion of the soils, whether directly or through bio-accumulating plants; and

2. Leach tests had demonstrated the availability of the contaminants to be low and consequently the material posed no threat to the water environment.

The Environment Agency accepted this argument and consequently the material was used on site as fill. This decision saved the client in excess of £100,000 in relation to landfill costs.

4.3.5 Case Study #5: Remediation of Former Builders Yard, SE England.

This site is to be redeveloped by a property developer as an office development. Preliminary investigations suggested the site was contaminated and on investigation diesel contamination was found on the surface of the site in made ground and below ground in relation to disused storage tanks in granular materials. Although this site is to be developed for offices it is situated next to a residential development and it is situated on an aquifer with local abstractions. Consequently, the remediation of the diesel contamination is to occur. The remediation of organic contaminants in granular soil is an application particularly suited to the use of biological treatment techniques. Furthermore, the site is of a sufficient size to allow the efficient use of ex-situ treatment techniques with the soil being treated in a single batch. However, the consultant engineer working on this site did not consider such techniques for use at this site with the justification that at 600m^3, the volume of contaminated material would not justify treatment- despite the assertion that biological treatments of granular soils can be economical down to volumes as low as 300m^3, according to the remediation contractors contacted by the author in Cases 1 and 2. Consequently, the option was not considered and the client not informed of the possibility of such an approach. Whether or not biological treatment would have been used in this particular case in not certain. Indeed it is possible that its use would

have been discounted as the redevelopment of the site has been proceeding relatively quickly on the instructions of the client. However, without such information the client is not in a position to consider all the options.

In this case the client was keen to undertake the investigation as quickly as possible in order to allow a decision to be made on the purchase of the site. Consequently, the investigation had to be planned without prior knowledge of the layout of the proposed development on the site. After the investigation had taken place the plans for the development were made available. These revealed that additional investigation work was required as a significant thickness of made ground was discovered in the vicinity of the foundations of the proposed office development. The plans for the development were not influenced by the geoenvironmental investigation, the possibility of altering the development based on the findings of the investigation and remediation requirements have not been considered as the developer wishes to develop the site rapidly and the investigation could not be planned around the proposed development due to a lack of information.

4.3.6 Case Study #6:Investigation of Former Power Station Site, NE England

The redevelopment of this site is proposed for retail and leisure use. However, the redevelopment of the site is still at an early stage and the investigation of this site was instigated at the request of the Local Authority with responsibility, under PPG23, to undertake the redevelopment of contaminated land in a planning led process. The investigation had the dual purpose of establishing the extent and nature of the contamination on site but also providing the Local Authority with information it required in its attempt to understand the nature of this former industrial area. The history of the site is such that extensive contamination was considered likely. This site is relatively large and the contamination present can be characterised into a number of distinct types of made ground relating to different land uses. Significant contamination was found on the site with respect to mineral oils and heavy metals but not in situations that are considered to pose an immediate threat to human health. However, PAH contamination was found at the surface of one area of the site at significantly elevated concentrations. This contamination remains and is considered a threat to human health and the environment. Remedial action to address this contamination has been recommended although more detailed data is required before a remedial options can be considered. Further monitoring and testing is to occur after negotiations with the Local Authority have been conducted. It is anticipated that these negotiations will result in a number of planning conditions which specify the levels of remedial action and monitoring required at the site.

4.4 SUMMARY

This chapter contains- in a summarised form- the opinions of 32 individuals that represent the broad spectrum of the contaminated land industry and 6 case studies, based upon the author's work experience in the contaminated land industry. The information is in part specific to the problems of developing treatment techniques and in part more general. As Section 4.2.7 states, much of the information collected is only coherent when considered in its entirety. Consequently, much of the information does not fit precisely with the phenomena identified in Chapter 2.

The selection of a simple method of presentation was due to the increasingly complex nature of the information being analysed. The following chapter attempts to address this by bringing together: the information that is presented here; the phenomena described in Chapter 2; and, specific examples or cases from other sources.

5. DISCUSSION

5.1 OVERVIEW

The objective of this research, identified in Section 1.2 of Chapter 1, is to investigate the dynamics of the process by which techniques for the remedial treatment of contaminated land evolve. It was stated in Section 1.3 that little research had been carried out into the nature of the dynamics of technological innovation; and, it was proposed that the development of techniques for the remedial treatment of contaminated land is due to the interaction of the factors listed in Table 17.

Table 17: Factors Which Influence the Development of Treatment Techniques

- the objectives and effects of environmental policy and law;
- the criteria used by industry to select technology for commercial use; and,
- the research and development of new remedial techniques.

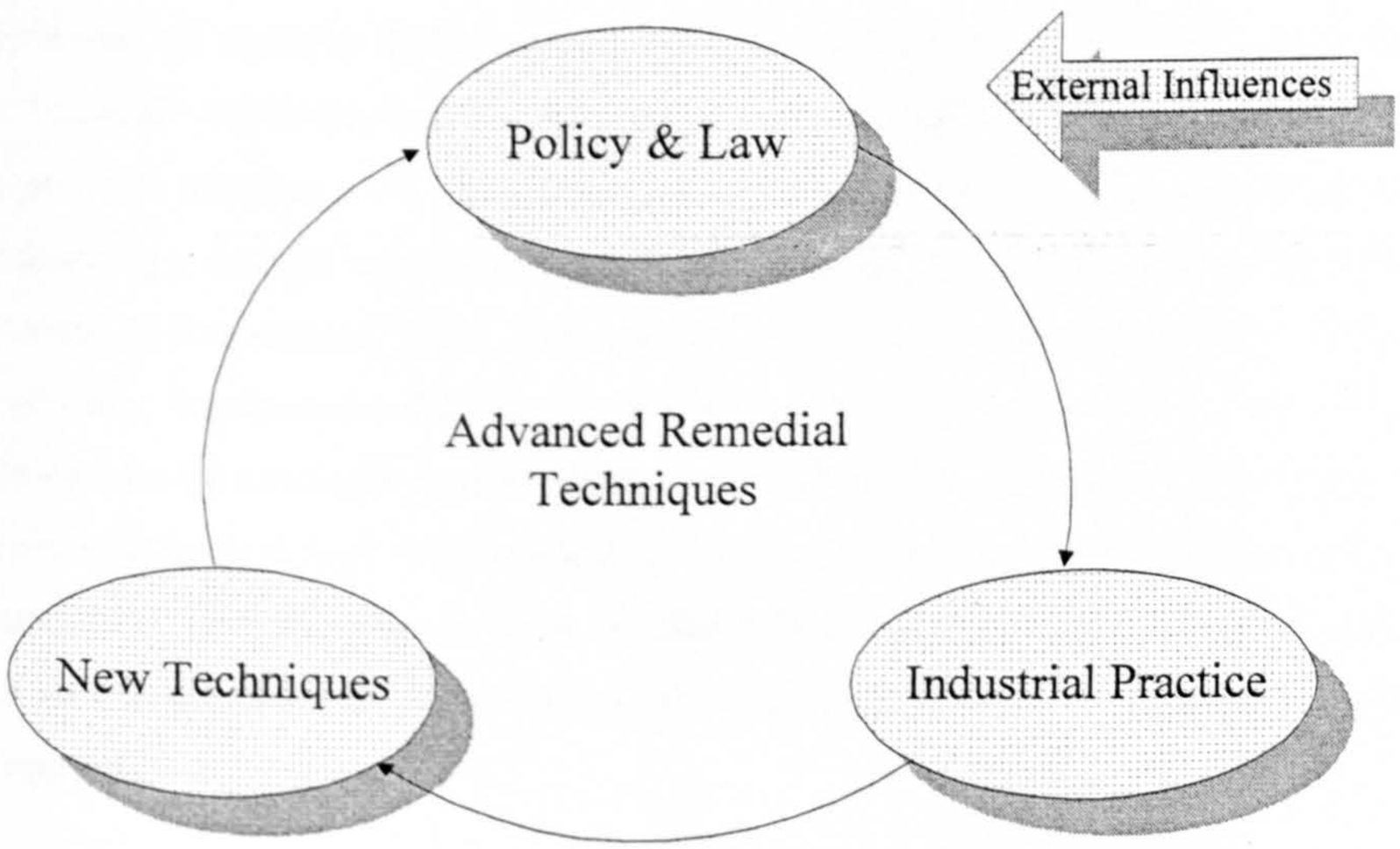

Figure 9: The Dynamic System

Figure 9 illustrates the situation this research seeks to explore. It also illustrates "External Influences". The aim of Chapter 2 was to identify these influences and, therefore, provide a theoretical foundation, based

upon literature, for the study of the dynamics of development of techniques for the treatment of contaminated land. Consequently, a range of disciplines were reviewed including, economic theory, environmental economics, environmental policy, the regulation of contaminated land, the provision of guidance on the redevelopment of contaminated land, the abilities of treatment techniques and their development and the development of strategies for the investigation and remediation of contaminated land. This provided a theoretical understanding of the dynamics of development of treatment techniques and facilitated the development of the research questions listed in Table 18.

Table 18: Research Questions

Question: What are the influences of policy instruments designed to address the problem of contaminated land?
Question: What is the influence of public opinion on the use and development of techniques for the treatment of contaminated land?
Question: What is the influence of awareness of contaminated land and contaminated land liability in the business community?
Question: What are the influences of measures designed to stimulate the use and development of techniques for the treatment of contaminated land?
Question: What is the influence of the level of scientific understanding of, and the technical ability to deal with, contaminated land?

Chapter 3 reviewed the research methodologies available and justified, on the basis of the difficulties of quantifying "cultural" influences on the development of treatment techniques, a study of qualitative information and the selection of a phenomenological research method. The unfamiliar nature of the research methodology decided upon necessitated the adoption of the well established research design method developed by Oppenheim (1992). This research design method was adapted for use in a concurrent manner. In addition, it provided a framework for the development of the methodology. This concurrent approach allowed for the continual reconceptualisation of the methodology as the research progressed and enabled the research methodology to be adapted as experience was gained. Structured interviews followed up by questionnaires were the primary form of information collection. The interviews transcripts were written up as soon as possible after the event. The findings of the earlier interviews were used to direct the consequent research.

In addition to the interview information, six case studies, based upon the author's own experiences of working in the contaminated land industry, are presented. The case studies were considered necessary due to the need to address a lack of information relating to the owners and developers of contaminated land.

In Chapter 4, the information collected in the interviews is presented as a series of short summaries. The aim of this chapter is to provide a succinct account of the information collected and to demonstrate its validity both in terms of the roles of the individuals interviewed and the nature of the information collected from them.

5.2 Overview of the Discussion

In the following Sections of this chapter the results, presented in Chapter 4, are critically assessed within the context of this and prior research as identified in Chapter 2. The research questions (or phenomena as they are termed in Chapter 3) are addressed in turn but the somewhat arbitrary distinctions they draw between the various influences on the development of treatment techniques means the discussion does tend to combine the way in which these phenomena are addressed. This is considered inevitable as the influences on the development of treatment techniques do not exist in isolation.

Where reference is made to an interview summary in Chapter 4, the initials of the interviewees are used. Where reference is made to a case study the number is used. Table 19 gives the initials of the interviewees used and the sections of Chapter 4 to which they correspond.

5.2.1 Delimitations of the Research

The aim of this discussion is to critically assess the information gathered in the interviews and case studies and to use this to provide insights into the process by which treatment techniques are developed for use. However, it is important to understand the delimitations of the research method used in this report as this has a bearing on the way in which the information can be interpreted and assessed. Although the illustration of the dynamics of development presented in Figure 9 is wholly original in its conception, it is emphasised that as a model it merely represents the basic elements of process by which techniques for the remedial treatment of contaminated land are developed. As such it can be compared to the concept of Boldon's cornerstones of analysis in relation to reinforced soil walls. This concept was developed to explain the function of reinforced soil structures but in itself can only help in the actual design of such a structure through the way in which it allows the overall concepts at work to be understood. This is also the purpose of the illustration of the Dynamic System in Figure 9.

It is recognised that the information provided in the interviews and case studies of Chapter 4 can be characterised in the following ways:

- the information is biased in so far as it is a representation of the views and experiences of those individuals interviewed or that are described in case studies; and,

- the information is not wholly representative of the contaminated land industry as a model can never truly represent the complexities of the real world.

However, these characteristics are not only acceptable in the context of a qualitative research project of this kind, but, in the case of bias, is essential if any meaning is to be gained from the information. This concept has already been explored in Section 3.2.3 but is reiterated here. Hakim (1987) states:

> "Qualitative research (and by this implies qualitative research based upon survey data in the social sciences) is concerned with individuals' own accounts of their attitudes, motivations and behaviour" and "although qualitative research is about people as the central unit of account, it is not about particular individuals *per se*; reports focus rather on the various patterns, or clusters, of attitudes and related behaviour that emerge from the interviews".

In relation to this research this implies that the bias inherent in the views of the individuals interviewed (and in the way in which decisions are made and reported in the case studies) is what is important. It is the understanding of this bias and the way in which it influences the development of treatment techniques which is the aim of the discussion. This is why contextual information about the interviewees is important (see Section 4.1.1). However, it is also important to note that whether or not the opinions of the interviewees are considered *correct* from one particular standpoint or opinion- this does not invalidate the opinion of the individual. In fact, it is these differences in opinion which directly influence the dynamics of the development of treatment techniques.

However, although it is important to recognise that these differences in opinions are what influence the dynamics of development- it is also dangerous to assume that such a study, based upon a particular group of individuals, can be used to make generalisations that are directly relevant in all situations. This is because any interpretations which are made, based as they are upon the opinions of individuals, are only useful as they provide *specific* examples of the way in which phenomena occur. Consequently, it is only possible to build a partial picture of the way in which a system operates, something which is true of all models which can never hope to recreate the full complexity of the real world. Therefore, a further aim of the discussion is the enhancement of understanding of the dynamics of the development of treatment techniques through the illumination of some of the complex interactions which are involved in this process, but not necessarily the development of overall truths. i.e. the examination of examples that add to our understanding of this complex process and which illuminate the comparatively simple model presented in Figure 9.

In Chapter 2, the external influences illustrated in Figure 9 were developed further to give the five phenomena listed in Table 18. These research questions provide an indication of the range of influences on the development of treatment techniques. It is demonstrated in the following Sections that these research

questions, or phenomena, are somewhat arbitrary in their definition as the barriers between them are indistinct. However, what these five areas of investigation do is provide a general framework for the analysis of the evolution and development of techniques for the remedial treatment of contaminated land. Just as Figure 9 is a graphical representation of the processes and mechanisms this research seeks to examine, the five phenomena listed in Table 18 are a vehicle for studying the complex changes in political, technical and scientific understanding.

The following sections also illustrate that although the influences on the development of treatment techniques are indistinct, the opinions of the interviewees in this research tend to be more rigid and confined to particular areas of expertise. This reflects the fact that the contaminated land industry is comprised of and requires the input of a wide range of professionals from a variety of backgrounds. Indeed, it was because of the desire to study the full range of influences on the development of treatment techniques, not solely from a technical viewpoint, that interviewees from a range of disciplines were approached. It was also the reason why further case studies were considered necessary to enhance the information relating to property developers or landowners involved with contaminated sites.

Table 19: The locations of Interview Summaries

Interviewee	Organisation	Initial	Section #
Dr R. Lageman	Geokinetics (Netherlands)	RL	4.2.1
Brian Street, Tony Lennon & John Warr	ECS Underwriting & Fielding Smeaton & Jones	BS	4.2.2
Prof Judith Denner	DoE	JD	4.2.3
Dr Mary Harris	Monitor Environmental (formerly Clayton)	MH	4.2.4
Philip Crowcroft	Aspinwall & Company	PC	4.2.5
Kelvin Potter	ICI	KP	4.2.6
Neil McLeod	Envirotreat Ltd	NM	4.2.7
Mark Dyer	Mark Dyer Associates	MD	4.2.8
Ian Burbidge & Cameron M. Scott	Graesser International	IB	4.2.9
Gavin Costigan	DTI and JEMU	GC	4.2.10
Glenn Jones	Biolytic	GJ	4.2.11
Brian Lassmann	Eco-Logic	BL	4.2.12
Linda Fiedler	USEPA TIO (Washington D.C.)	LF	4.2.13
Michelle Simon	USEPA (Cincinnati)	MS	4.2.14
Edwin Barth	USEPA (Cincinnati)	EBth	4.2.15
Round Table Discussion	USEPA (Cincinnati)	RT	4.2.16
Ed Bates	USEPA (Cincinnati)	EBts	4.2.17
John Martin	USEPA (Cincinnati)	JM	4.2.18
Kandi Brown	IT Corporation (California)	KB	4.2.19
Neil Davies	Geosyntec (Atlanta)	ND	4.2.20
Randy Sullivan	Golders (Atlanta)	RS	4.2.21
Dr Stephan Jefferis	Golders (UK)	SJ	4.2.22
Malcolm Lowe	DoE	ML	4.2.23
Prof Malcolm Grant	University of Cambridge	MG	4.2.24
Stephen Tromans	Simmons & Simmons	ST	4.2.25
Jim Begley	AEA Technology	JB	4.2.26

5.3 THE VAGARIES OF PUBLIC OPINION

An opinion that is widely held in the literature suggests that public opinion, as a result of the disasters at Lekkerkerk and the Love Canal, had a major influence on the introduction of the contaminated land regimes of the Netherlands and United States (Anon 1994; LaGrega et al. 1994; Luigies 1991; Wentz 1995). KP suggests the Love Canal incident has had such a profound effect as to have moved into American folk law. The reaction of the public to environmental incidents is well known and, as Section 2.3.2 highlights, quite deliberate regulatory transparency is recognised as a way in which policy makers can encourage compliance (Wills 1995; Wills and Jones 1996b). However, as Section 2.6.7 outlines, public opinion can influence the development of remedial techniques in a variety of ways. In their work involving the validation of treatment techniques under the USEPA SITE Scheme, LF and JM provide examples of this variability in public perception. LF described how public fear of the release of hazardous substances to the atmosphere has given ex-situ treatment techniques a bad reputation. JM observed that despite moves to relax stringent remediation standards, the strength of public opinion in some areas can prevent their adoption. Similarly, KB suggests that despite attempts to educate both the public and regulators when using remedial techniques, it is inevitable that the more high profile the site the more education and assurances have to be provided. Despite the fact that the SITE scheme can involve the verification of techniques in their earlier stages of development, which understandably could cause concern amongst local residents, these example illustrate the vagaries of public opinion in relation to the use of treatment techniques in different situations. These examples illustrate that public opinion can both promote and hinder the use of treatment techniques and thus concur with the work of Crowcroft (1992) and Sanning (1990) that consider public opinion to be both a driving force and barrier to the development and use of treatment techniques.

As consultant environmental engineers KP and RS are familiar with the processes of hazard identification and assessment, risk estimation, risk evaluation and risk control in association with the redevelopment of contaminated land. Consequently, their experience lends weight the their observations and explanations for the variations in public opinion that include observations on the public perception of risk. They observe that:

- contaminated land is an emotive subject;
- the risks involved and not widely understood by the general public and can be misrepresented by the media;
- the public have a poor perception of risk; and,

- factors such as the value of land, the risks associated with treatment and encapsulation, and the differences between short and long term risk all colour public opinion.

Assuming these observations are a reasonable representation of public opinion, they provide an explanation for EBts suggestions that the regulatory culture associated with contaminated land, and particularly that in the United States, can be characterised by a low level of public recognition interspersed with periods of attention sparked by public opinion that influences policy in phases. Indeed, RS also considers the regulation in the United States to be reactive and characterised by short periods of intense activity interspersed with long periods where regulators are left to enforce and interpret legislation. A situation he believes has occurred with the evolution of CERCLA and RCRA.

5.4 Regulation and the Development of Treatment Techniques

RL is considered a valid commentator on the influence of strict liability and stringent regulation on the development of treatment techniques as he has experience developing treatment techniques in the Netherlands and the United Kingdom in association with AEA Technology. Consequently, his perspective includes both stringent and comparatively lax regulatory environments. KP's knowledge of the this situation stems from his work for IMS10.

RL concurs with Alm's (1991) argument that stringent regulation and strict liability can enable the development of treatment techniques and provides an illustration of the difficulties of developing a treatment technique in the absence of a supportive regulatory environment. He describes the necessity of validating and field testing a treatment technique in order to gain the level of experience necessary to develop it commercially. He also points out that the development of his own technique was only possible in the Netherlands as a result of steadily increasing landfill prices. Interestingly, RL also agrees with Jacoby and Ermich (1991) and Luken and Fraas (1993) who suggest that strict liability and stringent environmental standards can be restrictive. Both RL and KP support the arguments in Sections 2.3.2 that command and control policies are inefficient and that the solution to this problem lies with more flexible forms of legislation as espoused by Hahn 1993; MacDonald and Kavanaugh 1995; Andrews 1995; and, Clinton and Gore 1995. Here the view of RL carries particular weight due to his position as the developer and vendor of a treatment technique who admits he owes his success to stringent Dutch clean-up standards. RS, a consultant environmental engineer in the United States, also recognises the problem and describes the federal Superfund programme as adversarial, rigid, and restrictive. He also believes that in contrast, the state regulation of RCRA is considered less confrontational and that it offers more realistic standards based upon waste streams. In reaction to these problems the majority of the interviewees, both from the United Kingdom and United States, recognise moves toward the regulation of contaminated land by a *suitable for use* type approach. This illustrates the growing recognition in all parts of the contaminated land field of a

move toward more pragmatic approaches to the clean-up. In addition, interviewees from the United States cited the abolition of the *preference for treatment* policy, where treatment techniques are preferentially specified over more traditional civil engineering based methods, as an indication of a move away from prescription to more pragmatic approaches (LF, JM, Ebth, RT). LF referred to this trend and a realisation that the levels of protection commonly required by Superfund are unrealistic. She also emphasised the influence of studies by the GAO which have highlighted such inefficiencies in the United States.

It has been discussed in the literature how policy makers find it difficult to balance the stimulation of environmental technology and the deregulation of industry (Section 2.4) (Smith 1991; Wilkes 1995; Wilkes 1996). It is understandable that Wilks, as a representative of the Environmental Industries Commission[15], would favour the introduction of regulation to stimulate the use and development of treatment techniques- and he does so by arguing that such policies are short sighted and will prevent British firms gaining access to lucrative global markets for treatment technologies. However, Smith (1991), who was instrumental in the development of the United Kingdom's approach to contaminated land through the development of the ICRCL guidance, also concurs with this view albeit for the reasons of pragmatism and cost effectiveness in the redevelopment of contaminated sites. A view recognised by JD who further developed the United Kingdom's recent policy approach as head of the DoE's Contaminated Land and Liabilities Division prior to her move to the Environment Agency.

In contrast to the views of the policy makers, PC and GJ argue that the civil law and the current contaminated land legislation are inherently weak and that Section 57 will not draw in a large number of sites, although it may encourage the pre-emptive clean-up of land. PC believes that although the EA have powers they will not be fully enforced and developers will wait and see what are the minimum requirements and this is what will dictate the level of compliance in the country. He believes the level of compliance will not be as high as envisaged through the rigorous interpretation of the act as the agencies will not wish to become involved in the legal battles that would, they feel, follow if a confrontational approach were adopted. However, it is emphasised that these are the views of environmental consultants and the vendors of remedial techniques who have a vested interest in the introduction of more stringent clean-up standards, consequently, such a stance is understandable. These vested interests are highlighted by Yong (1998) as a characteristic of the different elements of the industry. However, there is a reluctance by policy makers in the United Kingdom (and this is confirmed by ML- who replaced JD as the head of the contaminated land and liabilities division of the DoE) to follow the Superfund route of chasing polluters through the courts for the costs of clean-up. Consequently, the arguments of the vendors and consultants do

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[15] The Environmental Industries Commission (EIC) are an organisation that lobby on behalf of the developers of environmental technology.

appear to carry some weight. Without the threat of strict liability and stringent regulations, there is less emphasis placed upon making the polluters of contaminated land pay to clean-up contaminated sites in the United Kingdom than in the United States. However, the presence of stringent clean-up standards does not imply that treatment techniques will necessarily be used in the place of more traditional civil-engineering based methods unless other methods to encourage their use and development are also introduced, such as the landfill tax or the US land-bans. Therefore, the use of treatment techniques can be seen to need not only stringent legislation to enforce the clean-up of contaminated land but also the requirement that such techniques be used. This is reflected by the work of authors such as Leach and Goodger (1991) and Daley (1989) where the uptake of treatment techniques in the United Kingdom can be seen to be less than that in the United States where the land-bans required the use of such techniques.

These views and opinions illustrate a paradox- for policy to stimulate the use and development of treatment techniques there appears to be the need for stringent environmental standards. Standards are, however, commonly associated with inefficiency and bureaucracy and may not result in the most efficient or cost effective remedial treatment of contaminated land (Wills and Jones 1996a). Indeed, RT and JM, who are responsible for the verification of treatment techniques under the USEPA SITE Scheme, confirm the assertion, in Section 2.6.1, that the Superfund programme spawned a reactive, regulation driven market for environmental technology. This assertion has also been reported in the literature (Conner 1994; LaGrega et al. 1994). In addition, the Draconian standards and administrative problems of Superfund are also recognised by JM, Blacker and Goodman (1994) and MacDonald and Kavanaugh (1995).

5.4.1 Extensive techniques.

An effect of this situation is reported by ND, a consultant environmental engineer working in the United States, and also by RL in the Netherlands. They both contend that the inflexible and stringent clean-up requirements can hinder the use and development of efficient treatment techniques. RL maintains that treatment techniques cannot operate efficiently at 100% of their theoretical ability but by requiring such techniques to operate at close to these limits cost efficiency is greatly reduced. RL and ND suggest that lower standards would enable treatment techniques to compete effectively at sites where current stringent clean-up requirements prohibit their use. These interviewees describe a paradoxical situation where the use of treatment techniques are prescribed but the clean-up standards to which they must conform are so stringent that the techniques cannot achieve them.

However, it is apparent that the majority of the interviewees recognise the need for cost efficiency and flexibility in the remediation of contaminated land. MS and LF, both representatives of the USEPA, describe a move from the "intensive techniques", described in Section 2.6.5, toward more energy efficient and cost effective technology. KP, an environmental consultant in the United Kingdom, suggests pragmatic

regimes place the emphasis on the incremental reduction of cost. These opinions correspond with the findings of the NATO/CCMS Pilot Studies detailed in Section 2.6.5 concerning the emerging trends in new treatment techniques (Bardos 1991; Bardos 1994b; USEPA 1995b). Indeed, a growing recognition of a need for cost efficiency in the remedial treatment of contaminated land is confirmed by the majority of interviewees. The removal of the *preference for treatment* requirement in the United States, reported by LF, JM and Ebth of the USEPA, testifies to this. This effectively indicates the relaxation of the prescriptive requirement that treatment techniques be used. Indeed, it is widely believed that environmental policy is encouraging the use of extensive- low key treatments where possible (EBth, LF, KB, MD, JB, JM, NM, KP and MH).

However, it is emphasised that although policy may be encouraging the use of a particular approach, and policy makers can state the objectives of their approach, it does not necessarily follow that a policies introduction will be immediate or successful.

5.5 SUITABLE FOR USE

JD and MH suggest that the United Kingdom's contaminated land regime has developed from, and owes its success to, the planning system and that this has enabled the efficient regulation and redevelopment of contaminated land. However, JD also states that the Section 143 Registers failed because of political lobbying and because it did not conform with the Department's overall policy objectives. In contrast, JD, MD and MH consider *suitable for use* to be the philosophical extension of the planning system and that it provides a pragmatic system for the regulation of contaminated land by encouraging voluntary, planning led redevelopment. ML concurs and suggests that the intention of the new regime is to: improve the clarity of the existing regime in terms of the range of controls (this is the role of the statutory guidance and the EA); to clarify ambiguous definitions (such as the definition of harm in the present regulations on statutory nuisance); and to reinforce the concept of *suitable for use.*

This concurs with Section 2.3.2 that highlights aspects of ecologically modern policies and the notion that modern environmental policies should aim to remove unacceptable actual or potential risks to health or the environment by the most appropriate and cost effective means (DoE 1992; Freshfields 1994; Perdue 1991). However, JD, who was the head of the DoE Contaminated Land and Liabilities Division while the *suitable for use* concept was being developed from the existing contaminated land policy, accepts that this approach is at odds with prescriptive technological requirements. This illustrates the dilemma faced by policy makers in relation to the efficient and economic clean-up of contaminated land and the development of new treatment techniques. However, these accounts of the development of the *suitable for use* approach, given as they are by those charged with the responsibility of developing these policies, tend not to emphasise the uncertainty that the prevarication surrounding the development of the United Kingdoms policy approach

has caused. For example, it is apparent that Section 57 of the EPA will now not be introduced until 1999 if at all. Consequently, there is still the possibility that it will follow the Section 143 Registers and not be introduced (Ends 1998). Furthermore, in their accounts of the development of the United Kingdom's policy approach, the policy makers do not acknowledge that the process of regulatory capture has influenced their decision making.

It is intended that the United Kingdom's *suitable for use* approach will use the planning system to bring contaminated land, or brownfields sites, back into use when they are redeveloped. Local authorities are charged with the responsibility of overseeing this plan-led approach (DoE 1995). GC, JD, ML and MH confirm that these are the objectives of *suitable for use* and as such they differ little from the approach outlined in ICRCL guidance. However, the ICRCL guidance is not law. The *suitable for use* approach does differs from the current guidance based approach in that the Environment Act 1995 formalises the common law liabilities already in use and aims to enable a civil law framework with statutory controls (GC).

SJ, who has conducted a review of the technical implications of the *suitable for use* policy (Jefferis 1996) is of the opinion that common law will remain an important aspect of the regulation of environmental pollution because statutory liability in the United Kingdom is only geared towards the prevention of *serious* threats to health and the environment. He is of the opinion that under the Environment Act 1995 "contaminated land" is relatively narrowly defined particularly as it requires that: "Without the identification of all three elements of a pollution linkage, land should not be identified as contaminated land.". The mere existence of a contaminant in, on or under land does not make it contaminated land. This explicit requirement for a linkage sets the United Kingdom's definition apart.

It has been suggested in the literature that this narrow definition has been influenced by the Department's previous attempts at the introduction of contaminated land legislation (Cairney 1993; DoE 1994a; DoE 1994b; Ends 1993a; Rossi 1995). Indeed, ML does state that the large amount of consultation that has been undertaken on Section 57 was in part caused by the dramatic reaction to the proposed Section 143 registers. He also stated that the regime focuses on realism and "hard policy choices". MG contends that these policy choices result in a narrow definition that could lead to the development of funding gap between the redevelopment process and orphan sites. i.e., the redevelopment process will deal with the less contaminated sites but not the more heavily contaminated sites that, despite their state, do not qualify as contaminated land under Section 57 of the Environment Act 1995. He suggests planning gain could be used to bridge this gap and solve the problems of brownfield redevelopment by underpinning it with the planning process (Grant 1996).

A number of interviewees consider there to be a developing emphasis on brownfield development and that this a further aspect of the recognition of the need for efficiency in the regulation of contaminated land

(EB, KP, LF, ST, ML and JD). Brownfield sites represent a wide range of contaminated sites in the broad sense of the meaning, not that defined in the Environment Act 1995. The notion that the United Kingdom has, in its planning regulations, a well developed system for dealing with brownfield redevelopment is supported, particularly by those who were instrumental in the development of the United Kingdom's policy approach (JD, MH, and ML). This position is supported by the literature and particularly by the range of ICRCL guidance that illustrates that a redevelopment based approach to contaminated land has been recommended for use in the United Kingdom for many years. The emphasis on the redevelopment of derelict and contaminated land in the United Kingdom is illustrated by the work carried out by English Partnerships and measures such as the Derelict Land Grants. These illustrations of the emphasis on the redevelopment of brownfield sites notwithstanding, an increased emphasis on the redevelopment of brownfield development can be seen to be part of a general need for efficiency in relation to the redevelopment of contaminated land. This is considered particularly relevant by authors such as Maldonado 1996 who contends it reflects a recognition of the inefficiency of federal regulation in the United States where the Brownfield Action Agenda encourages states and cities to develop brownfield sites in urban areas. It appears that both the United States and the Netherlands are moving towards a more pragmatic approach to regulation where remedial treatment follows the *suitable for use* approach (LF)(Ends 1997a). Maldonado considers the main reason such emphasis is being placed on the efficient redevelopment of brownfield sites under state as opposed to federal supervision is the specter of joint, strict retroactive liability that accompanies the Superfund regime- not an inability to redevelop such sites. RS contends the prescriptive nature of the Superfund system and the strict liability that accompanies it are increasingly seen as inefficient in the United States (RS), this view is emphasised by a number of reports by the United States General Accounting Office (GAO 1997a; GAO 1997c; GAO 1997d). This is supported by a widely held belief within the USEPA, as represented by the interviewees from the USEPA, that when Superfund is reauthorised it will no longer contain a *preference for treatment*. LF, JM, RT and EBth suggest this is partly due to the influence of the Republican Congress who are sympathetic towards an industrial lobby that has been pushing for more pragmatic and less adversarial forms of regulation- whilst RS suggests a realisation of the potential cost of remediating DOE and DOD sites has prompted Congress to study the problems caused by contaminated land regulation. Examples of this include Non-Time-Critical (NTC) remedial actions which allows Responsible Parties, who have a good track record of compliance with regulation, to forego certain administrative aspects of the Superfund process in order to speed the remediation process and, as a consequence, reduce their costs (GAO 1996b). The USEPA is also keen to emphasise that most contaminated sites are to be treated as brownfield, as opposed to Superfund, sites (RS).

In contrast, the emphasis on the efficient redevelopment of brownfield sites in the United Kingdom appears to have been developed out of the existing policy that has been in place for many years. Whatever the

reasons for the adoption of such policy approaches, it is apparent that the adoption of pragmatic- non confrontational regulatory approaches that recognise the need for efficiency in the redevelopment of contaminated land are considered appropriate on both sides of the Atlantic.

A further aspect of the policy relating to brownfield redevelopment is suggested by both ST and MD. They believe that the cost of redeveloping brownfield sites will fall to the developers of the sites. ST suggests contaminated land policy is moving very much towards ensuring, so far as possible, that remediation occurs as a pre-condition to development. MD suggests policy is moving toward the transfer of liabilities to the purchasers of land. In such a situation the price of the land should reflect the fact that it is contaminated and the amount of remedial work that will be required to develop the site for a particular end use.

The opponents of this system contend it fails in a number of ways. The first of these has been described above. ST and MG believe a funding gap may develop between the most seriously contaminated sites and those that pose low risks to health and the environment.

It is apparent that in order to prevent such a gap occurring the cost of redeveloping contaminated sites needs to be kept to a minimum. This is also the argument used by the lobby against the introduction of the Section 143 registers and the landfill tax on contaminated soil who suggested an increase in the cost of landfill or the reduction of the value of land by its blight would prevent redevelopment rather than ensure redevelopment is carried out to higher standards. Therefore, it in not that the *suitable for use* policy prevents the use of treatment techniques in brownfield sites, it is that the risks posed by the presence of contamination on a site are addressed by whatever form of remediation is used- be this by the isolation of contaminants beneath hardstanding or its remediation using a treatment technique.

The detractors of the *suitable for use* policy, who include the vendors of remedial techniques, their representatives such as the EIC and individuals such as Sir Hugh Rossi[16], believe the result of this policy is uncertainty, which is discussed below, and a weak remedial treatment industry which is poorly equipped to take advantage of a growing global market for environmental technology (PC, GJ and NM)(Rossi 1995; Smith 1991; Wilkes 1995; Wilkes 1996). They argue that the decision of the UK Government to adopt a deregulatory stance will inhibit the development of a market for advanced remedial techniques and therefore prevent entry to the international contaminated land market. Table 20 illustrates the size of the Western European market for remedial techniques up to 1995. It was a market worth 2.3 billion US dollars per annum and which was growing at a rapid rate. The study of the remedial treatment industry, conducted by the OECD (1994), described the UK's opportunities for growth in relation to contaminated land

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[16] Sir Hugh Rossi, former chairman of the House of Commons Select Committee.

remediation technology as "poor" (see Table 21). This view is a view supported by research carried out for the Joint Environmental Markets Unit (JEMU 1995)- a body established by the DTI and DoE to help British firms exploit opportunities in the environmental industry (see Table 22).

Table 20: Western European Land Remediation Growth (US$ billion), OECD (1994)

1990	1991	1995	Annual Growth (%)
1.0	1.1	2.3	16.1

Table 21: Global Sector Growth Opportunities in Contaminated Land, OECD (1994)

Region	High growth	Moderate Growth	Low Growth
Germany		✓	
France			✓
UK			✓
Italy			✓
USA	✓		
Australia	✓		

Table 22: UK Strengths in Relation to Opportunities in the World Environmental Market, (JEMU 1995)

	Technology	Systems/ Applications	Contracting/ Engineering	Operation	Maintenance/ Support
Air Pollution Control	✸	✸✸✸	✸	✸	✸
Water & Wastewater Treatment	✸	✸✸	✸	✸✸✸	✸✸✸
Waste Management	✸	✸✸	✸	✸✸✸	✸✸✸
Contaminated Land	✸✸✸	✸✸	✸✸✸	N/A	✸
Energy & Renewables	✸✸	✸✸✸	✸	✸✸✸	✸✸✸
Environmental Monitoring & Instrumentation	✸✸✸	✸✸✸	✸	✸✸✸	✸✸✸
Environmental Services	N/A	✸✸	✸	N/A	N/A

Key: ✸✸✸ High Value Opportunity — UK Strengths:
✸✸ Medium Value Opportunity
✸ Low value Opportunity

It is apparent, therefore, that the market for treatment techniques in the United Kingdom is not as strong as it is in overseas markets and the pragmatic policy approach adopted in the United Kingdoms is the cause. However, it is also apparent policy makers in the United States and the Netherlands are now implementing policies similar in nature to the *suitable for use* policy of the United Kingdom- suggesting stringent and prescriptive regimes are not efficient forms of regulation.

5.6 Uncertainty & Development

NM and GJ, both of whom are vendors of treatment techniques, highlight problems they perceive as significant barriers to the use and development of their techniques. They believe the exemption of contaminated soil from the Landfill Tax will hinder the development of remedial techniques in the United Kingdom and promote the use of landfill. Considered purely from the point of view of price, this is a reasonable assumption. An increase in the cost of landfilling contaminated soil would make treatment techniques appear more attractive.

The vendors of treatment techniques also emphasise the wider issue of uncertainty. A difference between a lack of regulation or economic incentives that encourage the development of treatment techniques- be they efficient or not- can be distinguished from the limiting effects prevarication in relation to the introduction such policies can cause. Clearly, in an industry that can be seen to rely on environmental policy for its existence (Economic Theory & Contaminated Land, Section 2.2)- prevarication in relation to the introduction of environmental legislation will create uncertainty and hinder the ability of firms in the industry to form long-term plans. Examples of such prevarication include (Wills and Jones 1996a):

- The failure of the Section 143 Registers;
- The exemption of contaminated soil from the landfill tax; and,
- The delay of the publication of the guidance on Section 57 of the Environment Act 1995 on a number of occasions.

Indeed, similar observations are made by NM, a developer and vendor of a treatment techniques, who believes the state has a responsibility to clarify standards and target objectives as this can create a stable environment in which to develop a technique. He also stated that due to a lack of such guidance in the United Kingdom, and in order to provide assurances concerning the abilities of his own treatment technique, he considered it necessary to adopt standards developed in the United States by the USEPA. Furthermore, PC emphasises the issue of the enforcement of environmental regulations.

Such prevarication in relation to the introduction of environmental legislation has occurred in both the United States and The United Kingdom. This has been discussed in Chapter 2 (Section 2.4.5) and is discussed further below in relation to the process of regulatory capture and how this has influenced the development of policy. The policy makers JD and ML do not comment on the uncertainty that prevarication can cause the vendors of treatment techniques but GC of the Dti does. Speaking prior to the announcement that the Guidance on the interpretation of Section 57 was to be further delayed until 1999 (four years after the publication of the Act to which they relate) GC was of the opinion that uncertainty relating to environmental liability does limit the redevelopment of brownfield sites. He also stated that much of this uncertainty would be relieved when the provisions of Section 57 of the Environment Act 1995 come into force.

5.7 Lobbying & Regulatory Capture

JD, MH, GC and ML, who include in their number two representatives of the DoE and one of the Dti, all recognise the influence of political lobbying on the development of environmental policy in the United Kingdom and suggest this as a reason for the failure of the Section 143 Registers. In addition, JD suggests

the Section 143 Registers failed because they did not conform with the Department's overall policy objectives, whilst MH contends they failed partly because they elevated contaminated land to being an environmental, as opposed to, a redevelopment issue. GC is of the opinion that even when environmental laws have undergone internal review and consultation they can still fail. He cites the example of the Section's final reading where the CBI and the Landowners Association realised its implications and lobbied against its introduction.

The interviewees involved in the development of policy in the United Kingdom (JD, GC and ML) do acknowledge the failure of some aspects of contaminated land policy. However, other interviewees, such as the vendors of remedial techniques and consultant environmental engineers such as PC, GJ and NM consider these failures to have hindered the development of their techniques. A possible cause of these policy failures is given by Wills and Jones (1996a) who suggest the process of regulatory capture, which is described in Section 0 (Turner et al. 1994), occurs in the United Kingdom in relation to contaminated land legislation. Indeed, the well reported failure of the Section 143 Registers (Section 0) and the exemption of contaminated soil from the Landfill Tax lend credence to this (Ends 1995b; Ends 1996a), as does MD who does not believe policy makers act cynically but that they are simply influenced by industry in their decision making- which is again a reasonable definition of regulatory capture. The policy makers face a dilemma and have to balance the (vested) interests of a number of sections of industry. These diverse interest include large multinational companies, who KP believes first recognised the problems associated with contaminated land in the early 1980s when the Love Canal disaster received widespread recognition but also other landowners, property developers and the developers of remedial techniques.

The final decision to make clarification an imperative for any future legislation (ML), which has resulted in the repeated delay of the introduction of the Guidance on the Interpretation of Section 57 of the Environmental Act 1995, indicates the problems that policy makers have in relation to the introduction of any statutory instrument relating to contaminated land.

5.7.1 The Landfill Tax and Section 143

The United Kingdom's Landfill Tax is an excellent and timely example of an economic incentive- an instrument used by policy makers that, based upon cost or risk benefit analysis and the modification of markets, is increasingly being considered an efficient way of achieving better environmental quality at a lower total cost (Hahn 1993).

When the Landfill Tax was first mooted in 1994 it was well received. Although its sole purpose was not the stimulation of treatment techniques, it was the Government's intention that the tax would seek to reflect the environmental costs of landfill. Indeed, the vendors of treatment techniques expected an increase in the

amount of contaminated land clean-up activity and a boost to the use of treatment techniques was predicted in publications such as the Ends Report (Ends 1995a). However, by the time it had been decided that the tax was to be introduced on a per ton basis, lobbying had already begun on behalf of the construction and landfill industries. Despite assertions by Her Majesty's Customs and Excise that there would be no exemptions from the tax, the Government made its first concessions in January 1996 (Ends 1995a; Ends 1995b). In March of that year, the Government bowed to pressure from industry and announced that most contaminated soil disposed of to landfill would be exempt (Ends 1996a).

In granting the exemptions, the Government placed greater weight on the need to minimise disincentives for redeveloping brownfield sites than to use the tax to stimulate the uptake of treatment techniques. However, despite this decision, this exemption may be short lived. As a result of counter lobbying and protestations by the Environmental Industries Commission and land remediation businesses, the Government has promised to review the situation in October 1998 (Ends 1996b). Furthermore, there is some irony in a recent admission by the DoE that the United Kingdom's environmental policy may not go far enough in the consideration of the wider costs and benefits of environmental regulation (DoE 1997; Ends 1997a).

The Landfill Tax, driven by the perceived need to internalise the external costs of landfilling contaminated soil, has the potential to increase the cost of landfill and therefore stimulate the market for and development of treatment techniques in a way that does not conflict with the *suitable for use* policy. The exemption of contaminated soil is seen by the vendors of remedial techniques as an example of how weak regulation is damaging the British environmental technology and service industry (Wilkes 1996). Indeed, studies have concluded that the position of British companies in this market is weak, mainly because most sites in the United Kingdom are remediated by removing or encapsulating contaminated soil (Ends 1996a).

The failure of the United Kingdom's registers of potentially contaminated land, that were to be introduced by Section 143 of the Environmental Protection Act 1990, has parallels with both the exemption of contaminated soil from the Landfill Tax and Superfund. All of these policies have had the ability to stimulate the development of treatment techniques and have done so to differing degrees- depending on the strength of political will to address the environmental costs of contaminated land. What is consistent, however, is the ability of powerful industrial lobbying to influence the introduction of policy.

The Registers were conceived as a part of a wider plan to identify, assess and deal with contaminated land. It was also recognised that the investigation and clean-up of contaminated land would require private funding. However, fierce lobbying by property developers and industry resulted in the Registers being abandoned on the basis they would cause public alarm, land blight and prevent redevelopment (Ends 1991b; Ends 1991d; Ends 1993a).

5.7.2 Private Firms Desire Confidentiality

Despite initiatives such as IMS10, private organisations are often wary of publicising their contaminated land problems (Section 2.6)(Bardos and Martin 1995). Indeed, the suggestion (RL) that there is a market for contaminated land remediation influenced by the effects of negative land values on the balance sheets and share prices of large companies is supported (RS and BL). Although, whether this will create a market for large scale clean-up projects is unsure. This is because high profile polluters, such as chemical companies, tend to opt to clean-up their land internally because of a fear of liability and adverse publicity (RS). However, when private organisations are dealing with their own problems they are more willing to risk using treatment techniques, although information gathered by such private organisations is not in the public domain. Consequently, the developers of the techniques used in these situations are commonly denied the publicity that it is suggested is vital to the demonstration and development of a technique for the remedial treatment of contaminated land (NM, EBts and BL).

5.8 The Stimulation and Verification of Treatment Techniques

The suggestion of authors such as Dowd (1988) and Lindsey and Kelly (1994) that the verification and demonstration of remedial techniques is of great importance in their development is supported, particularly by the consultant engineers KP, PC, NM and MH. These interviewees also suggest that to gain credibility and experience the vendors of remedial techniques should: test in the field and lab; participate in verification schemes; share the potential risks and benefits with interested parties; and, lobby for support from government. The views of the consultant engineers are important with respect to the selection of treatment techniques as they are influential in the selection and specification of treatment techniques. Therefore, the conservatism of their approach to the use of treatment techniques is influential in the use and development of treatment techniques. This conservatism is understandable and justifiable as consultant engineers can not be expected to use untried techniques. Furthermore, LF, RT, BS and MS all emphasised that the Responsible Parties, Potentially Responsible Parties and Appropriate People- identified as those parties and people liable for the clean-up of contaminated sites- have quick and efficient clean-up of land as their major concern, not the development of treatment techniques. This illustrates that the developers and vendors of treatment techniques have different priorities to environmental consultants and the developers of contaminated land. Consequently, not only is it difficult to persuade Responsible Parties to allow information on remedial work to be publicised, it is also difficult to secure co-operation in SITE demonstrations.

The SITE programme was introduced to help the developers of treatment techniques verify their techniques and therefore gain credibility. This objective is confirmed by JM who is head of the Contaminated Land Remediation branch of the USEPA and is responsible for the verification of treatment techniques under the

SITE programme. JM and, KB and NM who are the developers of treatment techniques, attest to the importance of schemes to provide independent verification. Indeed both KB and NM have benefited from such schemes. KB in the United States and NM under the ETIS scheme in the United Kingdom. JM and KB contend the SITE scheme plays an important role in the development of treatment techniques in the United States: it allows the collection of data; relieves uncertainty; and facilitates the full scale development of remedial techniques through their verification by the USEPA. In the United Kingdom, Envirotreat used the USEPA leachability standards as benchmarks when developing their technology. This helped secure Environmental Technology Innovation Scheme (ETIS) funding for their role in the development of standards for in situ remediation and afforded Envirotreat both funding and recognition (NM). However, Envirotreat were the only firm in the United Kingdom to benefit from this scheme. There is not the same level of emphasis placed on the stimulation of remedial techniques in the United Kingdom as in the United States.

Although the role of the SITE programme is supported by JM and by KB (who develops treatment techniques for IT Corporation) EBts and RT (also of the USEPA) highlight the problem faced by the small companies developing treatment techniques. They are of the opinion that despite the help of the SITE scheme, small firms commonly do not appreciate the problems associated with developing their techniques commercially. This is also recognised by GJ and NM, both vendors of treatment techniques working in small companies. However, GJ and NM differ in their support for measures such as the SITE programme. NM is supportive of such schemes and has benefited from the ETIS Scheme in the United Kingdom but GJ believes they are not helpful as such schemes can have lead times of the order of two years. Consequently, he contends the uncertainty involved means small firms cannot afford the time to apply. Indeed, MacDonald (1997) supports this opinion and cites examples of the vendors of treatment techniques deliberately staying away from the SITE programme due to the problem of long lag times between the completion of a technology demonstration and the publication of the test results.

It is discussed in Section 2.6.3 how it is apparent that since 1986, the USEPA have been successful in stimulating the use and development of treatment techniques. Despite the relaxation of prescriptive technology requirements, policy makers in the United States still perceive a need to stimulate the development of treatment techniques. Indeed, the kinds of problems encountered by the developers of remedial techniques are well recognised in the United States where a variety of schemes to promote their development exist:

- The Superfund Treatability Exemption allows the developers of remedial techniques to work on developing their processes without the pressures of compliance with licensing regulations;

- the Technology Innovation Office (TIO) of the USEPA provide data and guidance to Responsible Parties, that have been identified in Superfund cleanups, and other government departments such as the DOE (LF); and,

- the DOD and DOE run schemes where emerging technologies can be tested at contaminated government facilities (EBts and KB)

However, the representatives of the USEPA also recognised that the cost of the Superfund programme has been enormous. In addition, although some of the techniques developed in the United States during this time are now considered established, many techniques have not been able to meet the stringent clean-up standards required by Superfund. MacDonald (1997) highlights problems in the market for treatment techniques in the United States and describes a situation where, despite a $9 billion market for contaminated land clean-up in the early 1990's and the market's apparent promise, many investments in treatment techniques have failed. The reasons cited for this failure, which are based upon a United States National Research Council report, include fragmentation in the regulatory programme for contaminated sites (see section 5.6) but also to the financial interests of the owners and developers of contaminated sites. MacDonald's argument agrees with the developers of the treatment techniques and those members of the USEPA who believe that small firms are not equipped to develop and market treatment techniques due to:

- the costs of the verification process; and,

- delays in the redevelopment projects that can be caused by legal wrangles, bureaucratic delays or technical complexities- all of which cause cash-flow problems for small firms.

In contrast, larger companies such as IT Corporation are able overcome this situation through their size and reputation in the contaminated land field. This aids them in developing innovative techniques as clients recognise this experience but also they are able to take a longer term perspective on redevelopment projects which enables them to overcome the cash-flow problems caused by delays in the redevelopment process (KB).

KB of IT Corporation and MS and SJ of the USEPA suggest that treatment techniques have the ability to generate their own markets provided they make the cost efficient clean-up of complex contaminated sites feasible. However, IT are a large corporation with the ability to take a long term perspective on redevelopment projects. This enables them to overcome the cash-flow problems caused by delays in the redevelopment process. In addition, it has also been discussed above how public opinion can prevent the use of technically efficient techniques despite their suitability for a particular job.

Table 23 lists the properties that a number of interviewees consider will characterise successful remedial techniques in the future. It is emphasised that the views are dominated by those of consultant environmental engineers and the developers of treatment techniques as these were the individuals who felt able to comment on this issue. The views of these individuals are of significance as these opinions will inevitably have an influence on the varieties of treatment techniques which are considered for practical application. Indeed, it has already been discussed how engineers are justifiably reluctant to consider techniques which do not have a demonstrable record- a situation which is reflected in the properties listed in Table 23 which, understandably, emphasise cost effectiveness, practicality and predictability. In addition, it is apparent that the interviewees from the United States emphasised the importance of low energy techniques, simplicity and longer term processes- possibly in response to the overly prescriptive use of extensive treatment techniques in the past.

Table 23: Predictions of Successful Remedial Techniques

Properties of successful remedial techniques:
Low energy and long term (MS, KP and KB);
Operational feasibility and simplicity (KP, MN, MS and KB);
Cost effectiveness (MH, PC, KP, KB and JB);
Best timelines to completion (JB);
Flexibility (MH);
Practicability and reliable (MH, PC and NM);
Assured end points (JB);
Applicability to the needs of the market and ability to operate in specific niches (MH);
Ability to operate without permits (PC);
Mobility (PC)
Dependent upon an understanding of the ability of the soil to attenuate contamination (MD).

5.9 VENDORS, CONSULTANTS AND DEVELOPERS

A number of trends involving the relationships between the vendors of treatment techniques, the developers of brownfield sites and consultant environmental engineers are apparent, based upon the author's work experience to date. The experience relates to work on a number of projects over a ten month period between June 1997 and March 1998 and has involved the investigation, assessment and remediation of derelict sites for industrial and residential use. The following findings draw on the author's general experience but with particular reference to a number of cases which are summarised in Chapter 4.

I. Biological treatment techniques are considered to offer the advantage that they can destroy contaminants. This makes them attractive as the destruction of contamination removes the liabilities associated with a site. This provides those techniques which do destroy or remove contamination with an advantage over techniques which encapsulate contaminants. This is because in some situations (Cases 2 and 3) there is a tendency amongst developers to require the total removal of contaminated material from a site, rather than the reduction of risks through the removal of contaminant pathways- despite the provisions of policies such as *suitable for use* which allow for such measures. Reasons for such decisions could be related to legal reasons (Case 3) or, as is described at III below, due to the need for rapid development of such sites.

II. The costs of biological techniques are demonstrably competitive with the removal of contaminated material and its disposal at a licensed waste disposal facility. Furthermore, in Cases 1 and 2 the vendors of the treatment techniques were all willing to provide cost and performance guarantees. In addition, the vendors contacted were all able to provide examples where their techniques had been used in the field (Cases 1 and 2).

III. The redevelopment process does not always accommodate the use of treatment techniques. This is manifest in the opinions of the developers of contaminated sites who commonly require rapid solutions to the problems caused by contamination. Indeed this was the situation in Cases 2,4 and 5 where when the property developers were consulted concerning there willingness to consider biological treatment techniques- all stated that work on the redevelopment of the sites in question was scheduled for no less than four months hence and that this did not allow for the use of such techniques. The reason for such short time frames in these situations are that the developers commonly have a land bank that they add to and develop on a rolling basis. Developers can only afford to hold a certain amount of land at any time so in order to maximise profits, the land they do hold needs to be developed and sold quickly.

IV. Experience has shown that due to the specialist nature of individual treatment techniques, their abilities are not necessarily understood by consultants and consequently clients can be left in a position of ignorance as to their abilities (Case 5). Although there is general understanding amongst environmental consultants of the general abilities of treatment techniques due to publications such as those by CIRIA (Harris *et al,* 1996a-e) or the ICE (Harris & Herbert, 1994), the different techniques on offer differ in their approach and applicability and therefore their specification is a complex task requiring a detailed understanding of the abilities of the individual commercial techniques, as was carried out for Cases 1 and 2. Consequently, environmental consultants with specialist knowledge of particular practitioner's technique and their abilities are

required if a technique is to be recommended, rather than general knowledge based upon guidance.

V. The ability of biological treatment techniques were questioned by developers when their use was suggested in Cases 1 and 2. The vendors of treatment techniques are attempting to remedy this situation and all the vendors approached in relation to Cases 1 and 2 stated a willingness to demonstrate there remedial techniques by arranging visits to sites where their techniques are in operation or to come and give presentations of the abilities of their techniques. All the vendors of the remedial techniques approached were willing to offer guarantees on the costs and abilities of their techniques in terms of target clean-up levels. However, they also all declined to offer guarantees on the time their techniques would take. This illustrates their own confidence in their techniques to perform but also highlights a weakness of treatment techniques- the vendors of treatment techniques are not willing to provide guarantees in the area property developers emphasise as being important in the development of contaminated sites.

VI. ICRCL guidance emphasises the importance making a development fit the site. However, in cases 4 and 5 the redevelopment process from initial investigation to the commencement of remedial work was carried out in such a short period of time as to make this impractical. Furthermore, in these cases it was not possible to alter the development in order to take account of the contamination which was present or even to conduct the development in accordance with the development plans. This would not have required a change in the end uses of the sites but in Case 4 could have reduced the amount of contaminated material that required removal by encapsulating the material beneath hardstandings and in Case 5 would have resulted in only one phase of investigation being required. In contrast, Case 6 illustrates an investigation being carried out well in advance of redevelopment. Consequently, the owners and potential developers of the site will have the ability to make the development fit the site and facilitate the design of an effective remedial strategy.

VII. Case 3 illustrates that the ICRCL TTC can be treated as definitive limits, rather than used in conjunction with professional judgement in situations where the ICRCL TTC are exceeded, as suggested in the guidance. This can be as a result of legal influences, as illustrated by Case 3, although the author has experienced situations when reviewing environmental investigations carried out by other organisations where limits have been used in this manner. Furthermore, although the guidance issued by the ICRCL is by no means comprehensive, it is apparent to the author that in some investigations there is a tendency to only test for those determinands which are represented in ICRCL guidance, rather than to look at the probable/possible contaminants which may be present on a particular site.

VIII. There is inconsistency in relation to the interpretation of the waste management licensing regulations. It is apparent that the various regional offices of the Environment Agency take different views as to whether contaminated soil should be classified as waste and therefore whether or not it requires a waste management license. This can create uncertainty in relation to the remediation of contaminated sites and can cause significant variability in remediation costs. This is because in some regions where the agency adopts a pragmatic approach contaminated material may be retained on site, provided it poses no threat to human health or the environment (Case 5). However, in others regions, where a strict interpretation of the law is taken, the "waste" may have to be removed for disposal at landfill and the resulting voids filled with clean material. Furthermore, and considering the managerial constraints on remedial treatment, the time involved in obtaining a license– which is usually in the region of six months - can prevent the use of treatment techniques. Indeed, this was stated as a reason for not considering treatment techniques in Case 5 and has been emphasised by a recent example in Kent where a bioremediation project has been prevented from proceeding for this very reason [ENDS 1998].

6. CONCLUSIONS

6.1 THE DYNAMICS OF DEVELOPMENT

The illustration of the dynamic system presented in Figure 9: The Dynamic System, represents an overview of the process by which techniques for the remedial treatment of contaminated land evolve. However, this model is only intended to represent this process on the most basic level. What it does illustrate are the elements that must act in harmony if the development of such remedial treatment techniques is to proceed. The model appears simple but the relationships between the various elements are complex, as illustrated by the specific examples of these relationships provided in the Discussion Chapter and the conclusions which are based upon these specific examples. What these examples do is facilitate better understanding of the processes at work in the development of treatment techniques, but it is emphasised that what they do not provide are universal truths in relation to the development of treatment techniques- the examples add to our understanding of the situation but not are assumed to provide definitive answers.

Although the development of this model of the dynamics of the development of techniques for the remedial treatment of contaminated land is wholly original in this particular application, a similar concept has been applied in the field of reinforced soil. Bolton's Cornerstones of Analysis (Bolton 1990) provides a simple illustration of the behaviour of a reinforced soil structure. Although Bolton's approach is an iterative one used to develop a solution for a reinforced soil system, its similarities with the illustration of the dynamic system presented in Figure 9: The Dynamic System, relate to the way it represents an interpretation of a complex process. The illustration does not allow you to design a reinforced soil system, but what it does is illustrate the interrelationship of the complex elements that make up the analysis of such a system. Similarly, Figure 9 represents the main influences on the dynamics of the development of treatment techniques while the discussion above enables conclusions about the complexities of the relationships between these elements to be made in relation to a series of specific examples.

The conclusions given in the following section are illustrations of the complex processes that influence the evolution and development of techniques for the remedial treatment of contaminated land. The model of the dynamics of the development of treatment techniques (illustrated in Figure 9) is revised in Figure 10. In this revised view of the dynamics of development the final phenomenon, which stresses the influence of the level of scientific, technical and political understanding of contaminated land (see Table 24) is represented graphically. Indeed, it is the intention of this revised model to suggests it is the progressive development of knowledge or understanding that has the greatest influence on the use and development of remedial techniques.

The justification for this argument is illustrated by the conclusions in the following section. The original phenomena that were to be investigated related to a range of phenomena including:

- environmental policy;
- public opinion;
- environmental liability;
- measures designed to stimulate the use and development of treatment techniques; and,
- the level of scientific understanding of and the technical ability to deal with contaminated land.

However, it is apparent from the conclusions drawn from the discussion that an important influence of the development of treatment techniques- whilst involving the above- is the influence of differing levels or priorities relating to scientific, technical and political understanding of these particular phenomena.

This is illustrated by the way in which the conclusions, which follow, whilst relating to a particular phenomena or influence on the development of treatment techniques, tend to illustrate that impediments to the efficient development of treatment techniques are caused by deficiencies in general scientific, technical or political understanding (i.e. a lack of fundamental knowledge or experience). Consequently, the disparities in understanding that result between the diverse factions that make up the contaminated land industry as scientific or technical knowledge changes, changes in policy are attempted or new techniques developed, result in "friction" in the system. In this sense, friction refers to the way in which these diverse factions (i.e. the engineers, lawyers, property developers, etc.) present barriers to the development or adoption of the most efficient solutions to the challenges posed by the necessity to remediate contaminated land.

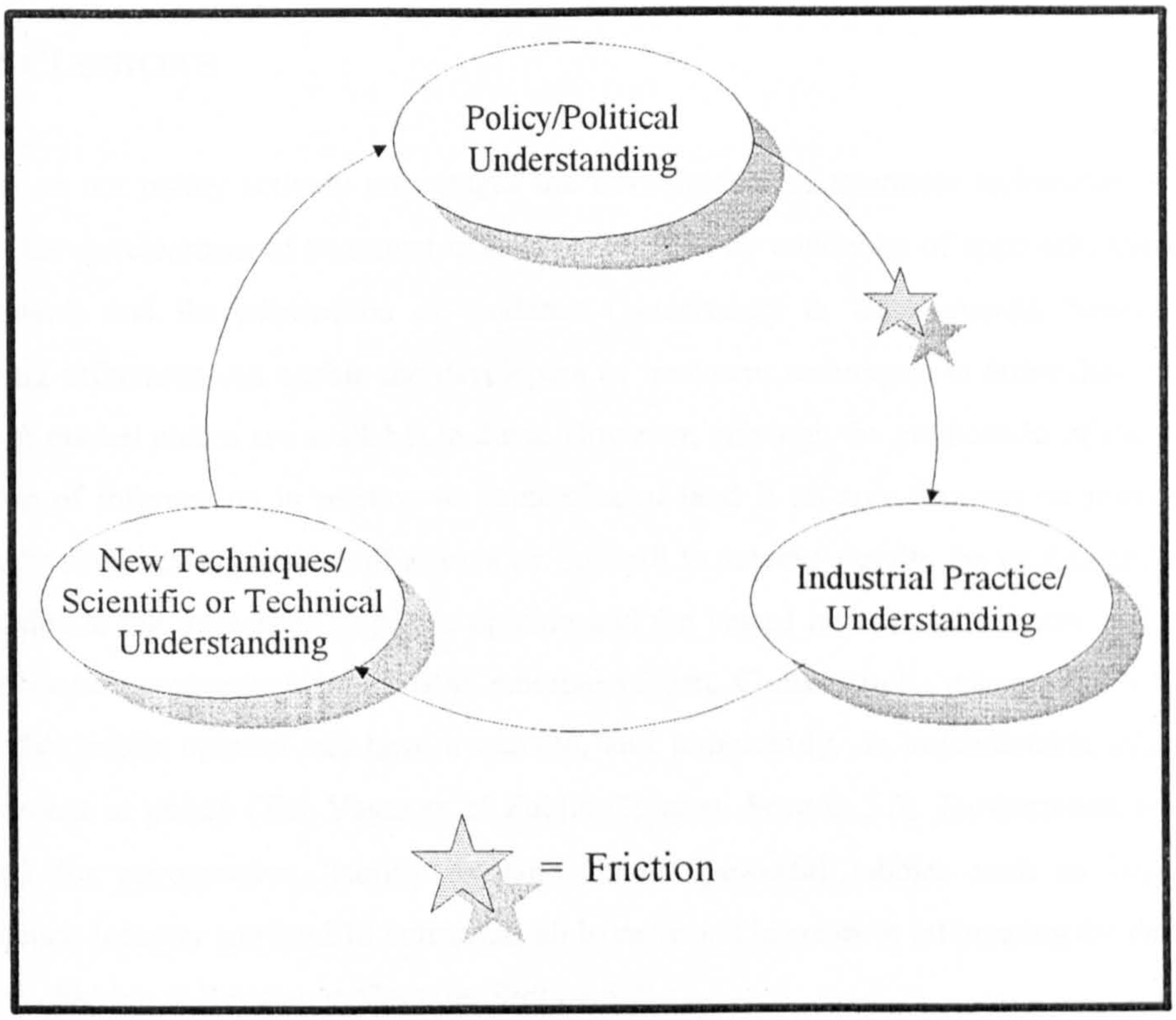

Figure 10: Revised Illustration of the Dynamics of Development

Table 24: Revised Phenomena

The influence of policy instruments designed to address the problem of contaminated land.
The influence of public opinion on the use and development of treatment techniques.
The influence of awareness of contaminated land and contaminated land liability in the business community.
The influence of measures designed to stimulate the use and development of techniques for the treatment of contaminated land.
The influence of the level of scientific, technical and political understanding of contaminated land.

6.2 CONCLUSIONS

1. Whether or not policy actively encourages the development of treatment techniques in a particular market, the development of treatment techniques is aided by continuity of approach, the development of standards and the publication of guidance (Uncertainty & Development, Section 5.6). Such stabilising influences can enable the developers of treatment techniques to tailor their approaches to whatever market niches are available to them. However, although the publication of standards and the provision of information in relation to contaminated land is an area that can be readily addressed, continuity of policy approach will always be difficult to achieve despite the best intentions of policy makers due to the influences of public opinion and the vested interests of industry and land owners. This is because contaminated land is an emotive subject. Consequently, concerns over health effects means that public opinion can have a marked, and importantly, an unpredictable influence on the development of policy (The Vagaries of Public Opinion, Section 5.3). Furthermore, because of the potential for retrospective liability or land blight- powerful lobbies such as landowners, the construction industry and landfill industries, all have vested interests in influencing the development of policy (Lobbying & Regulatory Capture, Section 5.7).

2. The adoption of stringent regulations and prescriptive approaches to the remedial treatment of contaminated land in the United States and the Netherlands suggests lobbying on behalf of industry or landowners has not had such a significant effect on the development of contaminated land policy. Conversely, in the United Kingdom political lobbying has played a major role in the development of contaminated land policy, to the extent that a large market for treatment techniques has not developed (Suitable for Use, Section 5.5). Experience from the United States and the Netherlands indicates that the markets for treatment techniques in these countries developed under regimes of stringent clean-up requirements, strict liability and the prescriptive or preferential use of treatment techniques. However, such conditions are not considered conducive to the development of the most efficient treatment techniques. Prescription stifles new techniques which do not conform to rigid regulatory requirements. Furthermore, stringent clean-up requirements limit the use of those techniques that tend to leave residual contamination. Consequently, contaminated land policy in the United States and the Netherlands is becoming increasingly pragmatic. This is illustrated by the adoption of forms of regulation similar to those espoused by the United Kingdom's *suitable for use* policy (Regulation and the Development of Treatment Techniques, Section 5.4 and Suitable for Use, Section 5.5).

3. The *suitable for use* concept represents a pragmatic, deregulatory approach to the regulation of contaminated land. The policy is an example of a mature environmental policy and it should achieve the desired effect of providing a realistic solution to the immediate health and environmental risks

posed by contaminated land (Suitable for Use, Section 5.5). However, policy decisions have and continue to be affected by vested interests and lobby groups and consequently, measures that would have stimulated the use and development of treatment techniques, such as the landfill tax or Section 143, have been prevented (Lobbying & Regulatory Capture, Section 5.7). There is a fine line to be drawn between imposing Draconian measures on industry and adopting a laissez faire attitude. The regulatory environment has encouraged cheap solutions to contaminated land problems in the United Kingdom. As a result, the incentive to develop treatment techniques has been minimal and the ability to offer sophisticated methods of remediation has left the United Kingdom firms with a handicap when competing in overseas markets (Suitable for Use, Section 5.5).

4. Uncertainty relating to the performance of treatment technique remains widespread and limits their use, particularly in relation to the time and cost of the techniques. This situation is exaggerated by a reluctance on the part of consultant engineers and their clients to use untried techniques and who wish to be certain of the outcome of a programme of remedial action (The Stimulation and Verification of Treatment Techniques, Section 5.8). The reluctance to adopt treatment techniques is also influenced by questions of future liability and the desire to remove problems from a site rather than risk ongoing liability. Measures such as an increase in landfill tax would remedy this to a certain extent, although undoubtedly this would prevent the redevelopment of marginal brownfield developments by increasing the cost of redevelopment. Furthermore, such a situation would exacerbate the current situation which places those techniques that do not remove the contamination from a site at a competitive disadvantage. This is because those techniques that rely on the removal of and the assessment of risks associated with contaminant pathways, rather than the direct removal or destruction of the contamination, are not favoured by developers who prefer the removal of all potential liabilities- despite the provisions of policies such as *suitable for use* which imply that both solutions are appropriate (Vendors, Consultants and Developers, Section 5.9). In addition, the advantages of many treatment techniques in particular situations are not always well understood by consultants or their clients and consequently techniques may not be considered even if they are suited to a particular application (The Stimulation and Verification of Treatment Techniques, Section 5.8).

5. Successful treatment techniques in an increasingly mature policy environment will be those that can provide timely, economical and predictable solutions to contaminated, and importantly, brownfield sites (The Stimulation and Verification of Treatment Techniques, Section 5.8). Such attributes will enable treatment techniques to be integrated within the increasingly risk management based approach to the remedial treatment of contaminated land, as dictated by the *suitable for use* approach, where decisions are made to accept a known or assessed risk and/or where actions to reduce the consequences or probabilities of an occurrence are applied in a pragmatic manner (Suitable for Use, Section 5.5). In this environment ex-situ techniques will have an advantage over in-situ techniques as

they are generally more predicable- allow greater accuracy in relation to the prediction of time scales and are commonly faster than in-situ techniques. Similarly, the use of extensive technologies for the redevelopment of brownfield sites are not considered viable in the majority of cases as such sites commonly involve low levels of contamination that suit comparatively low technology approaches, where viable, in combination with the selective removal of the most recalcitrant contaminants.

6. The development of an apparently efficient treatment technique does not necessarily imply the technique will be a commercial success. Environmental consultants and their clients are justifiably reluctant to use treatment techniques which have not been demonstrated in the field. Consequently, for a technique to be used in a commercial situation the emphasis on attaining verification falls to the developer of the technique. This requirement presents a real barrier to the use and development of treatment techniques as the developers of such techniques are commonly small firms without the financial resources to overcome this initial hurdle. Furthermore, the redevelopment process is also an uncertain one and delays of a legal, bureaucratic or technical nature can cause cash-flow problems for smaller firms. These problems have been recognised by policy makers and schemes such as SITE and ETIS have been introduced to address the problems of verification. These schemes can help to provide verification of a technique but involve long lead times and the cost of the project, if not the verification process, is borne by the developer of the treatment technique (The Stimulation and Verification of Treatment Techniques, Section 5.8).

7. If the vendors of treatment techniques are to gain greater market share, and their techniques are to be used in a wider variety of situations, a change in the way the developers of contaminated sites conduct the redevelopments will be required combined with a greater willingness on the part of the vendors of treatment techniques to provide accurate time estimates. The developers of contaminated sites commonly work to tight time frames and consequently do not consider treatment techniques as appropriate. Consequently, treatment techniques are not being used in situations where their use is possible because of the nature of the redevelopment process precludes their use (Vendors, Consultants and Developers, Section 5.9). The reluctance to use techniques is also caused by the complexity and number of treatment techniques available that may not be familiar even to the consultants which itself leaves their clients in a position of ignorance (The Stimulation and Verification of Treatment Techniques, Section 5.8). Consequently, treatment techniques may not be considered for use. In addition, the vendors of treatment techniques are reluctant to offer firm completion times, an approach not suited to the financially driven redevelopment market that places such importance on speed and predictability (Vendors, Consultants and Developers, Section 5.9).

6.3 CONTRIBUTIONS TO UNDERSTANDING

Therefore, and based upon the above, the contributions of this thesis are:

- the development of a model that facilitates the understanding of the complex processes which influence the development of techniques for the remedial treatment of contaminated land; and,
- a discussion of the dynamics of the development of treatment techniques, based upon a critical assessment of the opinions of practitioners within the industry- and the development of a number of conclusions based upon this assessment which further understanding of the dynamics of the development of treatment techniques.

The contribution and the originality of this research are also demonstrated by:

- the ability of this research to provide a response to the questions posed by a recent DoE Discussion Paper, which is described below; and,
- The publication of seven articles based upon this research- the most recent of which was subject to peer reviewed and has been published in a Geological Society Special Publication (Wills & Jones 1998). See Appendix 7.

6.3.1 The Wider Costs & Benefits of Environmental Policy

In February 1997, the Department of the Environment issued a Discussion Paper on the wider issues of the costs and benefits of environmental policy (DoE 1997). The paper aimed to initiate a debate with business and requested views on how the Department might better reflect the economic effects of environmental policy on the environmental technology industry.

The publication of this Discussion Paper is considered timely as it illustrates the need for information relating to the wider influences on the development of environmental technology as a whole and consequently, illustrates the originality of the contribution of this thesis. Furthermore, it lends credence to the methodology employed by this thesis as it is apparent that the way in which the DoE are seeking to understand the wider "cultural" influences on the development of environmental technology is through the collection of illustrative qualitative information.

The paper seeks answers to the following questions:

> ***"Can there be commercial benefit if environmental policy is more demanding than that of international competitors? If so, when and how might these arise? Examples?"***

It has been demonstrated that without stringent regulatory environments there is little impetus for the development of treatment technology and that such environments encourage the development of treatment techniques. This is evident in relation to the number of treatment techniques developed and available for use in the United Kingdom compared with the United States. As an example, Geokinetics have been able to test and develop remedial technology in the Netherlands aided by stringent regulation. This has enabled them to develop remedial technology in partnership with AEA Technology in United Kingdom (EBM 1996).

However, there remains some doubt as to whether techniques developed under stringent environmental regimes will necessarily be successful in a national perspective or at a commercial advantage in an international perspective. This research has identified a trend away from the prescriptive use of treatment techniques in the Netherlands and the United States- and, in the case of the United States, a trend which is accompanied by the indifferent performance of many companies developing and supplying such techniques. This latter trend may be due to a combination of the following:

1. That the contaminated land redevelopment business is inherently unpredictable and that this can cause problems for small firms, particularly whey attempting to build a market presence or track record; and

2. That environmental policy is moving away from the prescriptive use of treatment techniques and that the large regulatory driven market developed in the United States is based upon expensive and inefficient techniques that find it difficult to compete in an increasingly pragmatic policy environment.

> ***"What are the pros and cons for business of Government setting long term aspirational targets which provide a steer for strategic planning, but may be based on incomplete economic and scientific analysis?"***

This research has shown that the developers of treatment techniques consider the uncertainty that has surrounded the United Kingdom's policy approach to be a hindrance to the development of their techniques. As the successful use and development of treatment techniques has been shown to be dependant upon environmental regulation, it is readily apparent that in order to develop long term strategic plans for the development and marketing of such techniques that knowledge of the policy approach to be adopted is an advantage. As the situation described above details, the emphasis on contaminated land policy has recently shifted away from prescription and towards more pragmatic policy approaches. Consequently, in the United States and the Netherlands, the developers of treatment techniques that relied upon a stringent regulatory regime can be seen to be in a precarious position. However, even in the United Kingdom where the regulation of contaminated land has generally been a pragmatic affair, prevarication in relation to the promulgation of environmental regulation has created uncertainty in the market for treatment techniques. It is possible that the main uncertainties in relation to the way to best deal with the problem of

regulating contaminated land and its redevelopment have now been addressed and the use of pragmatic risk management approaches will create a more stable environment in which policies can be developed that can provide a direction for strategic planning. Although, the volatility of public opinion and the way in which this influences policy in phases cannot be discounted as a potential disruptive influence on the best conceived policy approach.

> ***"What kind of environmental measures are most likely to stimulate improvements in competitiveness and innovative responses?"***

The cliché that states "necessity is the mother of invention" is particularly apt in relation to this question. Economists have been able to demonstrate through the problems of common ownership that regulation is required in relation to environmental goods and services such as the amenity provided by land and groundwater. However, it is also apparent that attempts at addressing the problems of contaminated land have had different levels of success. This situation can be portrayed as a dilemma between the stringent regulation of contaminated land by the imposition of Draconian regulation verses the adoption of a laissez faire attitude. However, it is also clear that whether or not an environmental policy approach adopts stringent limits relating to the redevelopment of contaminated land, stability of policy approach is important as this enables long term strategic planning. Therefore, in situations where the social costs of an action are considered too great a price to pay, for example where the loss of amenity due to the disposal of contaminated soil to landfill, then the use of economic incentives is considered the most appropriate method. However, these measures are politically difficult to introduce due to the problems of regulatory capture as is illustrated by the attempted introduction of Section 143 and the landfill tax.

6.4 FURTHER RESEARCH

6.4.1 The Development of Remedial Techniques for Brownfield Redevelopment

Further research could reflect the importance of brownfield redevelopment. This could involve:

1. A study of the abilities of treatment techniques to tackle contaminated sites could be conducted that provided an assessment of how and where such techniques could actually be used.

2. A study of perceived abilities of the techniques as held by the vendors of the techniques, consultants and property developers.

3. An assessment of why treatment techniques are or are not used in particular situations.

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8. APPENDICES

8.1 APPENDIX 1: RESEARCH TIMETABLE

Table 25: Research Design (After Oppenheim 1992)

YEAR					96												97			
MONTH	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	
1	→	→	→	→	⇨	⇨													•	
2	→	→	→	→	→	→	→	→	→	→	→	→	→	⇨	⇨					
3	→	→	→	→	→	→	→	→	→	→	→	→	→	→	⇨					
4	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	⇨				
5			→	→	→	→	→	→	→	→	→	→	→	→	→	→	⇨	⇨		
6	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	⇨	
7	→	→	→	→	→	→	→	→	→	→	→	→	→	⇨	⇨					
8														→	→	→	→	→	→	
9	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	
10			→			→			→			→			→			→		

→ ACTIVITY

⇨ CONTINGENCY TIME

KEY

1	MAKE PRELIMINARY CONTACT
2	ARRANGE AND CONDUCT INTERVIEWS IN CONCURRENT FASHION
3	TAKE NOTES IN INTERVIEWS AND HAVE TRANSCRIPTS PRODUCED
4	ANALYSE INTERVIEW NOTES AND TRANSCRIPTS IN LOGBOOK FORM
5	FOLLOW UP ASPECTS OF INTERVIEWS
6	ONGOING LITERATURE REVIEW
7	WRITE FIRST DRAFT OF THESIS
8	WRITE FINAL DRAFT OF THESIS
9	ONGOING PROGRESS REVIEW
10	HOLD MEETING WITH SUPERVISORS TO REVIEW PROGRESS

8.2 APPENDIX 2: COMMUNICATIONS

8.2.1 Mk I Contact Letter, October 1995 - January 1996

UNIVERSITY
OF NEWCASTLE

Geotechnical Group
Department of Civil Engineering, Drummond Building
University of Newcastle, Newcastle upon Tyne NE1 7RU

18 December 1995

Dear Dr Harris

I am a Ph.D. student at the University of Newcastle working within the Department of Civil Engineering for Professor C.J.F.P. Jones. The Work I am conducting involves a study of the way in which techniques for the remedial treatment of contaminated land evolve.

My work, to date, has involved an extensive literature search from which I have drawn a number of conclusions. The main conclusion is that there are a number of phenomena that interact to enable or inhibit the successful development and uptake by industry of innovative techniques for the remedial treatment of contaminated land. These include:

- public awareness of contaminated land;
- business awareness of the problem of contaminated land and liability;
- technical ability to detect contamination and discover its effects;
- the use of policy instruments to address the contaminated land problem; and
- the incorporation of innovation into the dynamic.

Further, I propose that these phenomena interact in a dynamic manner within a framework made up of elements including policy and law, industry and technique and that this framework can be influence by outside factors such as public opinion or the action of pressure groups.

Your work relating to the costs of remediation and its implications for technology transfer is of great interest to me, and, as you will no doubt have realised, I am writing to ask for your help in relation to my work.

To further my work I have been talking to a number of individuals involved with contaminated land with the aim of demonstrating the dynamics of the process by which innovative techniques are developed and taken up by the market. This has involved the discussion of examples that illustrate the workings (and failings) of the process.

I enclose a document that summarises my work and its aims. I hope you will be willing to take part in my research and if so can we arrange a time to have a discussion.

I look forward to your response.

Yours sincerely

Julian G C Wills

8.2.2 Mk II Contact Letter, April-May 1996

UNIVERSITY
OF NEWCASTLE

Geotechnical Group
Department of Civil Engineering, Drummond Building
University of Newcastle, Newcastle upon Tyne NE1 7RU

22 May 1996

Dear Mr Lassman,

I read with interest the promotional material produced by ECO-Environmental Services Ltd.

I am conducting graduate research within the Geotechnical Group at the University of Newcastle. The work involves a study of the way in which techniques for the remedial treatment of contaminated land enter the market place. I have gathered from my research that taking a concept from the bench scale and expanding it to pilot or commercial scale is a difficult process. In addition I have the impression that advanced remedial techniques are only used in a very few cases in the United Kingdom. A situation I attribute to the relatively low cost of landfill (recent decisions on tax not helping), the perceived finality of landfill that removes the potential for liability, a pragmatic approach to problem solving within government and the fact that many remedial techniques are not sufficiently well developed to work or have no real track record.

I have been talking to individuals involved in the contaminated land industry in the course of my research. I would be grateful if I could discuss your work with you in more detail. Specifically I find it most interesting that you are working with an American firm. I assume the experience PXS have gained in the United States will be useful in marketing your services.

Would it be possible for me to come and talk to you for a couple of hours about your experiences of developing a remedial technique and your impressions of the contaminated land industry generally. If so I shall send you some more specific details of my work and what our discussion would involve. Any information you may give me will, if you wish, be treated in the strictest confidence.

Yours sincerely,

Julian Wills

8.2.3 Transcript Return and Questionnaire Cover Letter, August 1996

UNIVERSITY
OF NEWCASTLE

Geotechnical Group
Department of Civil Engineering, Drummond Building
University of Newcastle, Newcastle upon Tyne NE1 7RU

15 August 1996

Dear Mr Potter

Thank you for taking part in my research. As promised I enclose a copy of the transcript I made as a result of our discussion in July 1996. Please check over what I have written and make any corrections or comments you see fit.

As you will recall, my work is an attempt to study the dynamics of technological innovation in the contaminated land industry. By talking to yourself and other interviewees I feel I have built up quite a detailed picture of the process by which novel remedial techniques are developed and brought to market. The inevitable result of my labors is that I have developed a number of new areas I wish to look at in more detail.

Consequently may I request your help a final time. In addition to the transcript of our talk I have included some questions- some of which arose as a result of our discussion and some are of a more general nature. I would be grateful if you could answer the questions and return them to be by the beginning of November.

Please contact me if you have any further questions. I will ring you in a couple of weeks time to sort out any final details.

Thank you again for your help.

Yours sincerely

Julian G C Wills

8.2.4 Final Request Letter, October 1996

UNIVERSITY
OF NEWCASTLE

Geotechnical Group
Department of Civil Engineering, Drummond Building
University of Newcastle, Newcastle upon Tyne NE1 7RU

24 October 1996

Dear Mr Lassman

In August I sent you a transcript produced as a result of our discussion.

I am now preparing to write my final thesis and would remind you that you have not sent me any corrections or comments. If you wish I will send another copy of the transcript for you to look over.

If I do not here from you by Friday 8 November I will assume you do not wish to make any changes.

Thank you again for your help.

Yours sincerely

Julian G C Wills

p.s. I would also be grateful if you could have a go at the questionnaire and return it to me in the envelope provided. Thanks.

8.3 APPENDIX 3: BRIEFING DOCUMENT

Tulip Fund Scholarship-1996

Julian Wills, Geotechnical Group, Department of Civil Engineering,
Drummond Building, Newcastle University, Newcastle upon Tyne, NE1 7RU.
tel: 0191 222 6624 fax: 0191 222 6613 e-mail: j.g.wills@ncl.ac.uk

Itinerary

16-18 September Washington D.C.

19-22 September Cincinnati

23-27 September Atlanta

Background Information

The purpose of the research being carried out in the United States is to allow a comparative study to be conducted between the development of advanced remedial techniques in the United States and the United Kingdom. The following is a summary of the method that has been selected to allow the development of remedial techniques to be studied.

The Evolution and Development of Innovative Environmental Geotechniques

Frame of Reference

The following phenomena have been identified as factors that influence the evolution and development of techniques for the remedial treatment of contaminated land. The aim of my research is to identify detailed examples of these phenomena through the use of interviews. A number of examples of the type of information I am seeking have been given below along with the phenomena they illustrate.

public awareness of contaminated land problems, e.g. Love Canal, Lekkerkerk and Glory Hole;

business awareness of the problem of contaminated land and liability, e.g. The reaction of the insurance and banking industries to the proposed Section 143 Registers, the litigation associated with Superfund in the United States and the increasing need perceived by stakeholders to behave in a "green" manner;

technical ability to detect contamination and discover its effects, e.g. the effect of a change in the acceptable levels of PCE in water supplies that sparked the Cambridge Water case in the United Kingdom and the effect of stringent groundwater quality clean-up standards;

the use of policy instruments to address the contaminated land problem e.g. Superfund, the Environment Bill, the Dutch Standards and policy solutions such as the United States Brownfields Action Agenda or the United Kingdom's PPG23 that espouses the polluter pays principle and requires an emphasis to be placed on brownfield as opposed to greenfield development; and

the incorporation of innovation into the dynamic process, e.g. the SITE programme in the United States.

It is proposed that incidents such as Love Canal and Lekkerkerk brought the problems of contaminated land to the attention of the public and policy makers and had the effect of enabling a system with the potential of stimulating the development of treatment techniques (see Figure 1). In the United Kingdom there has been no such well publicised disaster although the system was enabled by a combination of factors including: the recognition of liability as a problem in the business community, possibly as a result of the events in the United States and more recent examples such as the Cambridge Water case; the increasing technical ability of scientists to recognise contamination; and the recent attempt to introduce a register of potentially contaminated land.

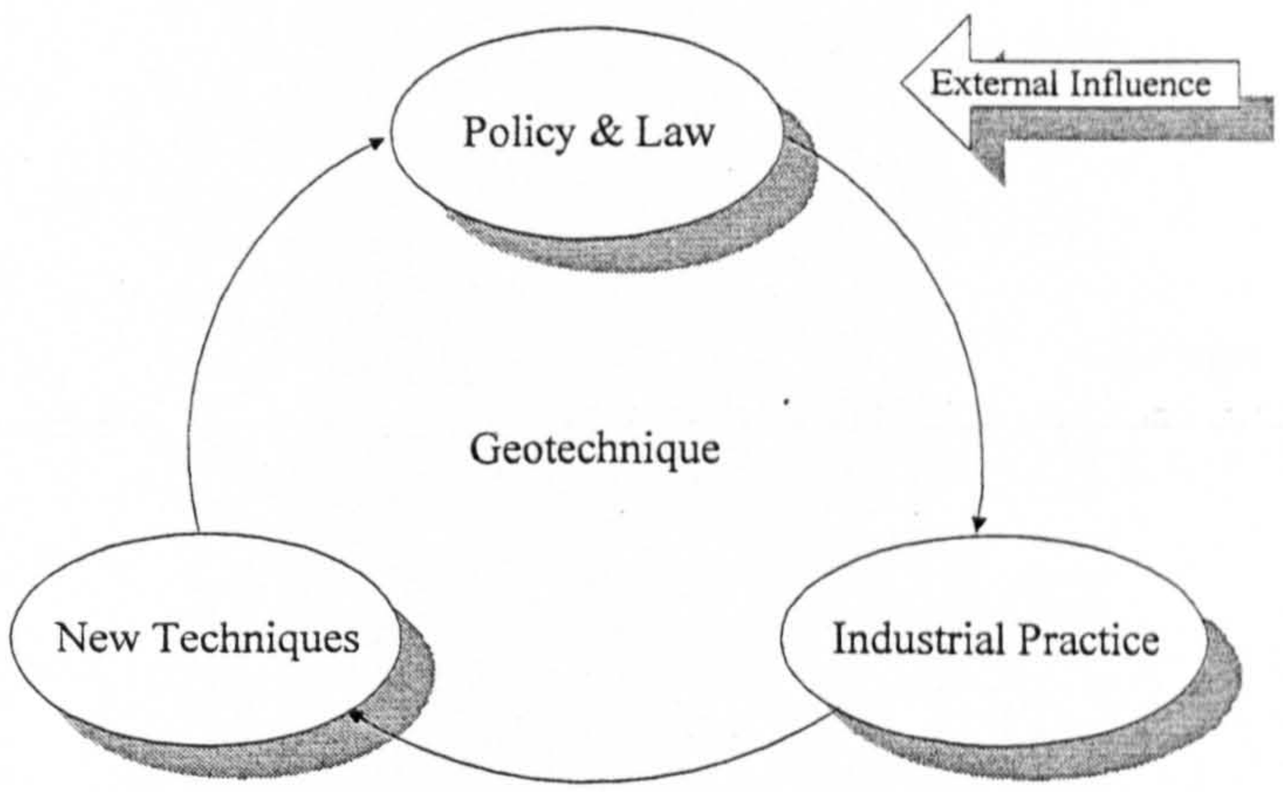


Figure 1: The Dynamic System That Facilitates the Development of Techniques for the Remedial Treatment of Contaminated Land

It is proposed that the phenomena listed above interact to influence the development of treatment techniques. In addition it is proposed that it is the function of policy to ensure these factors interact successfully. This successful interaction is required if techniques are to be developed for use in real situations.

The Interviews

I expect to conduct focused or unstructured interviews with participants. This implies that interviews will not involve a rigid agenda or the completion of a questionnaire. What they will involve is a conversation based around the frame of reference detailed above. Notes will be taken during the discussion and transcripts used in the production of my final thesis. The interviews should involve two main aspects:

1. the validity of the overall thesis;

2. and the discussion and identification of specific examples that can help to develop the thesis.

The purpose of the interview process is to gather data that illustrates the dynamics of technological innovation through the collection of illustrative examples and the discussion of the model pictured in figure 1. A number of individuals have been approached in relation to this research project. They come from a variety of disciplines with the express aim of achieving a representative cross section of the contaminated land field. It is understood that not all individuals will have knowledge of all aspects of the dynamic process. It is my intention to build a picture of the process from the collective insights of the individuals interviewed. With this in mind after a discussion of the general frame of reference the interviews will be directed along the lines dictated by the interviewees in relation to their understanding of the dynamics of the process.

8.4 APPENDIX 4: THE QUESTIONNAIRE

(N.B. the spaces between the questions have been removed in this Appendix)

UNIVERSITY
OF NEWCASTLE

Geotechnical Group
Department of Civil Engineering, Drummond Building
University of Newcastle, Newcastle upon Tyne NE1 7RU

Figure 1: the Dynamics of Innovation.

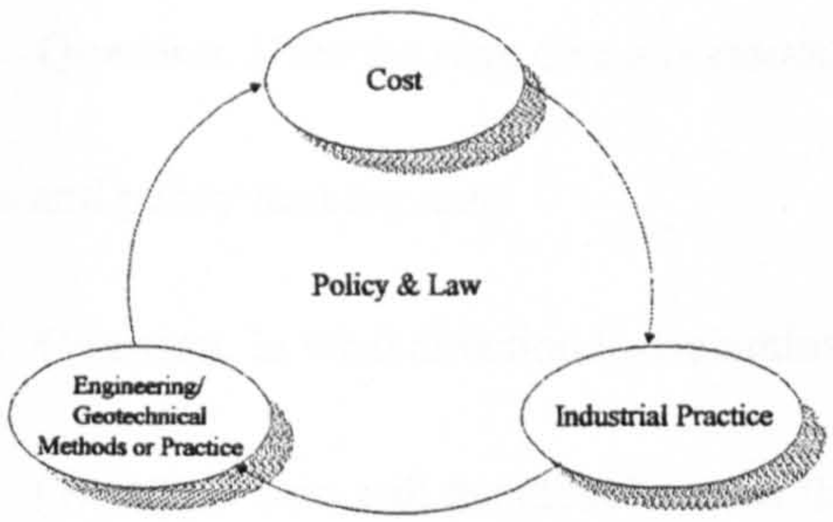
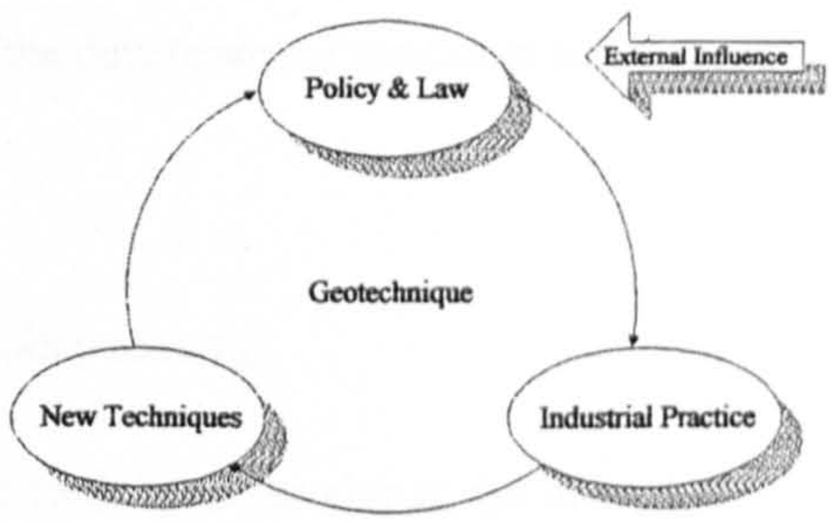


Figure 2: the Dynamics of Innovation.



Above are two figures that attempt to illustrate the basic process by which advanced techniques for the remedial treatment of contaminated land evolve. Figure 1 has policy and law at its centre with factors such as cost, technical methods and scientific knowledge as the driving forces. This suggests the central importance of policy and law to the development of remedial techniques and the way it drives the search for new methods. Figure 2 has the technical methods at the centre and policy, scientific understanding and industrial practice as the driving forces. This suggests that the practice of industry the level of scientific understanding and law react with each other and it is by this process that innovation is encouraged.

1. **Question**. Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

Interviewees identified uncertainty or confusion in a number of areas that influence the development of innovative remedial techniques.

2. **Question.** In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques?

3. **Question.** In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

Innovative remedial techniques require full scale field testing to instill confidence in their use. In addition, a commercial track record and quantifiable results are also seen as an advantage.

4. **Question.** How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

The protection of the environment is commonly considered to be the responsibility of government because of the inability of the market to account for the external environmental costs of goods and services.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

Markets and policy development.

6. **Question.** In what direction is contaminated land policy moving

7. **Question.** How will the global market for treatment techniques develop in the future?

8. **Question.** What types of remedial techniques will be successful...

...and what characteristics will they have?

9. **Question.** What are the most pressing threats and opportunities facing the vendors and developers of innovative techniques for the remedial treatment of contaminated land?

Thank you for your help. Please return this questionnaire to Julian Wills.

Geotechnical Group, Drummond Building, Newcastle University, NE1 4DA, Fax: 0191 2226613, Tel:0191 2226624,

e-mail: j.g.wills@ncl.ac.uk

8.5 APPENDIX 5: INTERVIEW TRANSCRIPTS

8.5.1 #1: Dr R. Lageman	
Occupation:	Director of contaminated land remediation company
Organisation:	Geokinetics Ltd, Rhenen, The Netherlands
Date of Interview:	25/October/1995

Dr Lageman is the director of Geokinetics Ltd. He founded Geokinetics Ltd in 1988 with a local government grant of NGL80000 and NGL1 million venture capital. Subsequently, the share of the company held by the initial investors has been taken by A.hac Ltd who provide office and lab space and funding for experimental work. Geokinetics are attempting to develop a suite of commercially viable electro-kinetic techniques for the remedial treatment of contaminated land.

Geokinetics currently offer two remedial techniques. The first technique they developed was electro-remediation for the in-situ removal of inorganic and organic contaminants. The technique involves applying a direct current to the soil by means of alternating cathode and anode electrode filter arrays. Contaminants are desorbed and transported to the electrode filters for capture and removal. More recently, they have developed electro-heating for the in-situ heating of soils in order to enhance the removal of volatile and semi volatile organic compounds. This technique is integrated with vacuum and/or groundwater extraction with the extracted volatile contaminants used to augment the power supply. In addition, work is being conducted on: an ex-situ electro-remediation batch process (a $1m^3$ test rig has been built and is undergoing tested); the use of osmosis to promote in-situ bioremediation techniques; and electrokinetic fencing to prevent contaminant plume migration.

Dr Lageman describes the electro-heating technique as a "bread and butter" technique. Initially, when the only technique offered by Geokinetics was electro-remediation, they experienced difficulty finding enough work. He attributes this to the fact that the technique is particularly specialised and quite expensive. The technique removes both inorganic and organic contaminants and is therefore not cost effective in situations where only organic contaminants are present. However, the electro-heating process fills precisely this role and is now in constant use both internally within A.hac and as a commercial process.

Dr Lageman believes the process of field testing the electro-remediation technique on a commercial basis, albeit at a loss, gave a valuable insight into the needs of the remediation market. He realised that the majority of work would involve the remediation of soils contaminated by organic contaminants such as fuel oil and that techniques do not work as well in heterogeneous soils as they do in the lab. This realisation prompted the

development of the integrated "bread and butter" technique. Integrated techniques work more efficiently as they do not require a single process to function at near 100% efficiency. They rely on a combination of techniques working together at less than their theoretically potential levels where efficiency is maximised.

The process of field testing has given Dr Lageman an insight into the practical use of his techniques. The use of the electro-heating technique to clean-up sites owned by A.hac has allowed for the building of plant and the fine tuning of the techniques in real situations. In addition, the use of the technique in such situations has helped Geokinetics to develop efficient procurement procedures. e.g., initially, the wells for the electro-heating process were formed by a hydraulic process. This process was efficient but caused problems in developed areas because of the noise and mess it produced. Consequently, future projects used continuous flight augers for the drilling of wells. Furthermore, it was realised that certain nutrients used for bioremediation techniques can be replaced by dishwasher powder that, although not as effective, is very cheap- the financial savings made in its use far outweighing any loss in efficiency.

Dr Lageman feels that the Dutch preference for field based testing means they are particularly good at producing realistic remedial techniques. He also believes that private firms in the Netherlands are better at marketing than their competitors in the United Kingdom and the United States. Dr Lageman described how Geokinetics illustrate this point. He founded the company in 1987 and since then about £3.5 million has been spent in development. At present Geokinetics are conducting a commercial operation to clean-up 3000m^3 of fine clayey sand and 5000m^3 of groundwater that has been contaminated with diesel and mineral oil. In the last year the turnover of Geokinetics was about £1 million. Dr Lageman considers this to be a modest budget. He also pointed out that he has two working techniques that are fully containerised and tested.

Dr Lageman criticised the way research is carried out in the United States. He described it as being too biased toward laboratory testing- techniques not being field tested until a vast amount of experimental work has been carried out. In addition, he feels that not enough emphasis is placed on the cost effectiveness of techniques, hence the relative lack of integrated technology (per dollar spent) emerging from the United States. For these reasons he feels that Dutch companies are in a strong position in the developing contaminated land industry, an industry that has yet to see a big boom in the use of technology as opposed to in consultancy where the majority of growth has been to date. He feels that this will occur when large companies have to come to terms with negative land values. Values that have not yet filtered through to the balance sheets of large companies and have therefore not affected share prices. When this occurs, as he feels is surely must, then there will be a market for large scale clean-up projects. e.g. projects running to hundreds of millions of pounds where a large company deals with its entire stock of contaminated land.

In relation to this lack of recognition of the contaminated land problem he proposed that not only is the market for contaminated land remediation immature but that this is also true of the regulations that govern the industry. He stated that the Dutch are especially concerned with the problems associated with groundwater

and that this seems obvious in relation to the hydrological conditions that predominate in the Netherlands. However, he also commented that the Germans are as concerned, if not more so, with long term aquifer recharge and the importance of water resources. This reflects a concern with environmental protection above a simple need driven by necessity. It illustrates the precautionary principle in operation. This, he suggests, is a reason why remediation, as opposed to encapsulation, is occurring in the Netherlands.

Dr Lageman described how contaminated land has been an issue in the Netherlands since the late 1970s when it became obvious that there were groundwater pollution problems. This process was given a final push by the Lekkerkerk incident that resulted in the Dutch standards and their system of rating land in one of three categories: a, b or c. Dr Lageman stated that the middle category has increasingly become obsolete leaving only an action level and ideal contaminant level. He also identified a problem with the Dutch system that requires a site found to be contaminated beyond the trigger value to be cleaned back to polished earth values. Consequently, much rests on reliable lab tests. He stated that lab tests are notoriously inaccurate with different laboratories providing results that differ by as much as 100% with relation to parts per million or parts per billion and that in a situation where threshold levels are stringent this is unreasonable. He suggested a more realistic system would be one based on orders of magnitude.

Dr Lageman considers the Dutch system of regulation too restrictive, although, he recognised a move towards more realistic legislation and a system more akin to the United Kingdom's *suitable for use* approach. He suggested that to clean-up 70% of the contamination found on a site would be far more cost effective than the current requirements to remove 95%. Although, again he conceded that the strict legal system adopted in the Netherlands has done much to promote the development of a remedial industry. e.g. landfill prices have been steadily increasing since the 1980s and now costs between £40-80/ton. Electrokinetic heating combined with vapour extraction costs £20/ton to operate and is offered by Geokinetics at £40/ton on a commercial basis. In the Netherlands if the cost of remediation is greater than £100/ton then the waste is sent to landfill. He also made reference to a case in the Netherlands that sets a date of 1975 for a cut off point for retrospective liability.

He contends that patents do not work as well in Europe as they do in the United States. He stated that when a patent is published competitors know what a process entails and can then work on a way of circumventing it. He considers it better to get a technique into the field as quickly as possible and gain practical experience of its operation. In this way competitors do not get to see the way a process works in detail.

8.5.2 #2: Brian Street, Tony Lennon and John Warr

Occupation:	Brian Street[+], Chartered Insurer and Director of Operations Tony Lennon[+], Senior Underwriter John Warr[•], Insurance Broker
Organisation:	ECS Underwriting[+], London, United Kingdom Fielding, Smeaton and Jones[•], London, United Kingdom
Date of Interview:	13/November/1995
Date of Seminar:	23/November/1995

The following account was produced after a meeting with the above at their offices in London. It also draws upon a paper by Mr Street (Street 1995) and a seminar conducted in the Royal Hotel, Edinburgh.

Mr Street described how the market for pollution insurance in the United Kingdom has been undergoing fundamental change. Prior to April 1991 liabilities arising from pollution incidents have generally been covered by standard public liability (PL) policies. It was common practice for PL policies to be issued, without any form of survey or inspection, to cover all the sites and locations used by the insured. It was also common practice not to charge extra premiums for pollution liabilities as underwriters did not perceive any risk in this area. Mr Street described a situation where free pollution cover was provided, with no aggregate limits and on an 'occurrence' basis. That is unlimited cover that, provided it can be shown that harm was caused during the period of the cover, can be claimed at any time in the future. By issuing such policies insurers have the potential to incur 'long tail' pollution liabilities. This implies they may have to face claims for gradual pollution damage which took place over many years but has only been recently identified as a threat.

Mr Street described how this is the same problem that has caused problems for Lloyd's of London in recent years. Superfund introduced a regime of strict, retroactive, joint and several liability in the United States that resulted in a raft of Third Party liability claims that led to the collapse of the American environmental insurance market and £8 billion losses for Lloyd's. These losses were all incurred as a result of PL policies. He pointed out that there is a dangerous attitude outside the United States that what happened in the United States cannot happen here. He described how European insurers, as a result of recent contaminated land related legislation, are following a similar path to that taken in the United States in the late 1970s to early

1980s. Specifically, the removal of cover for gradual pollution, followed by a total pollution exclusion on PL policies. He stated that in the United States, this course of events was followed by the total collapse of the environmental insurance market in 1984. Mr Street considers the threat to insurers' solvency to be very real, particularly as a result of class actions brought under common law as such cases only require proof on the balance of possibilities. By not charging any premiums to cover long tail pollution liabilities many insurers do not have the reserves to meet (he quoted Martyn Day):

"an onslaught of mass action litigation (under common law) on a scale never before seen in the United Kingdom, with hundreds and millions of pounds at stake".

Since April 1991, and a tightening of the wording of insurance policies by the Association of British Insurers (ABI), PL policies have no longer provided cover for gradual pollution. Most insurers have limited their policies to "sudden and accidental" polluting activities. There is no cover, since that date, for claims arising from gradual pollution or for defense costs arising from gradual incidents. In addition, in order for insurers to remain solvent due to long tail pollution liability claims, Mr Street contends that many insurers will seek to deny coverage under PL policies issued prior to April 1991. However, in the United States it has been decided that policies that intend to exclude gradual contamination and instead only provide cover for sudden and accidental pollution are not sound. Whether this will be the case in the United Kingdom has, however, not been tested. Such a decision may well be based upon a decision of whether pollution incidents such as explosions or acute poisoning can be considered sudden even though the contamination that caused the incidents may have taken place over many years. If this does not prove to be the case many companies will find that they are not insured for any gradual pollution caused after April 1991 and may not be covered for pollution incidents at all if they cannot show that the loss or liability arose during the currency of the policy and that the policy wording covered the event. Insurers will be looking closely at the policy terms, conditions and exclusions and will deny coverage if the insured: failed to take all reasonable precautions; deliberately caused the pollution; or failed to disclose material facts.

Therefore, although the 1995 Act will undoubtedly result in an increase in the number of claims under PL policies, many of these claims will not be paid. This will leave many companies with massive clean-up bills or, if the original polluters cannot be found, it will mean the land owners will be left with the bill.

Mr Street stated that members of the environmental insurance industry have responded to the problems that have arisen out of PL policies by offering a new form of environmental insurance. Although some insurers are still providing PL policies for sudden and accidental incidents, such cover is likely to be short lived and a total pollution exclusion is to be introduced in the near future by most of the major European re-insurers. The insurance industry is now preparing to undertake such an action (Ends 1995b). In October 1995, at the annual

gathering of re-insurers in Monte Carlo, Cologne Re, which underwrites a large proportion of British insurance policies, propose to remove support for PL policies in January 1997.

The future of environmental insurance is with Environmental Impairment Liability policies (EIL). The withdrawal of re-insurance support will encourage primary insurers to apply total pollution exclusions to PL policies and offer EIL cover instead. EIL cover will, in the future, depend on all sites to be insured requiring investigation at inception and then at every renewal. The initial investigation will be paid for by the proposers but the price will be refunded if the risk is bound. All further surveys will be paid for by the insurer. The policies provide full pollution cover, including gradual incidents, although the policies are to be issued on a claims made and reported basis. i.e. only claims made during the currency of the policy will be considered. This is an attempt to counter the effect of long tail pollution liabilities that have occurred with PL policies that have long since lapsed. However, cover can include an optional three year extended discovery period in case damage does not come to light immediately. Importantly, defence costs are also covered by the insurance. The introduction of EIL policies is an attempt to introduce realistic risk assessment into the environmental insurance process. In addition, for the first time cover is offered for First Party cover. This is a reaction to the need for protection from the costs of enforced clean-up operations. The cover is similar to that provided by EIL insurance. In addition to the requirements for standard EIL cover, these policies require a demonstration that the insured is taking pollution control seriously. This implies high levels of risk management and loss control, on an ongoing basis, to minimise the potential of polluting incidents.

The main problem with EIL cover are the premiums. At £15000 many companies cannot afford it. Mr Street sees this as a real problem for small to medium sized firms. This is because, although most major firms are well aware of their contaminated land problems and are already working on solutions, many small firms are totally unaware of the Environment Act and the fact that they may not be covered for environmental liability. In addition, many insurance brokers are not aware that EIL cover is available.

Mr Street considers the reason the problems encountered in the United States have not occurred in this county is because our regulatory regime has been ineffective. He stated that as a result there have been few claims relating to contaminated land. He referred to the way in which the COPA was ineffectual and degenerated into a farce because regulators failed to regulate. In addition, he stated how many of the most promising statutory instruments contained in the Water Resources Act 1989 and the Environmental Protection Act 1990 have also failed to be put to use. e.g. the prosecution of company directors involved in pollution incidents and the ability to remediate land and recover costs. However, he did say that he expects the Environment Act 1995 to be implemented far more effectively than the afore mentioned Acts.

Mr Street considers that the predominance of PL policies in the United Kingdom will be of real significance when the implications of the Environment Act 1995 are considered. Mr Street stated that the Environment Act introduces a statutory environmental liability regime which is:

- strict, i.e. there is no defence for "state of the art" or "compliance with regulations";

- retroactive, i.e. it has no cut-off date;

- joint, i.e. present and past polluters will be held liable for clean-up in proportion to the damage they caused; and

- several, i.e. if the original polluters cannot be found the current owner, even if innocent of causing the pollution of knowingly permitting it, will have to clean-up his own site.

Mr Street sees this as a deliberate attempt by the treasury to avoid paying for remedial action out of the public purse. The extent to which innocent owners have to pay for contaminated land clean-up remains to be seen, but this is also a problem recognised by lending institutions who are afraid that they may be treated as "deep pockets".

Mr Street, in reflecting on the problems the insurance industry has relating to PL policies and the Environment Act, stated that these issues will highlight the need for EIL policies. This relates to the statement by the DoE that it intends insurers and lenders to act in such a way as to provide economic incentives for remediation through the planning system. Prima facie, there does seem to be scope for the insurance industry to influence the market for remedial treatment. Mr Street described that there are many obvious benefits from having arranged both Third and First Party environmental liability coverage:

- regulators will see the business in a better light, the insured will be deemed more fit and proper if they have taken steps to make financial provision and submitted themselves to the rigorous inspection required by the professional insurers (Reflective: this is an economic incentive similar to the NTC programme in the United States);

- financial institutions will gain comfort from the existence of such insurance and be more prepared to advance funds;

- valuers will be able to enhance the asset value of sites so protected;

- accountants can feel safe in describing protected sites as an asset as opposed to worrying about them being a liability; and

- when a site is to be sold it will be more attractive to potential buyers, and their financial backers, if the site carries both forms of environmental liability coverage.

Mr Lennon does not see much incentive for the use of treatment techniques. However, he did concede that an expanding market for remediation of any kind will undoubtedly lead to an increased interest in the development of new technology. He stated that if the relative prices of remedial techniques can become more competitive then they will be taken up by the market and insurance companies will welcome this. What ECS do recommend is a thorough site investigation and risk assessment process. Considering the insurance industry is removing Third Party insurance cover from PL policies, if environmental insurance is to be taken out then it will increasingly have to be of the EIL variety. This will mean that if a company is to be insured then the minimum they must undertake is a basic desk study. If contamination is possible in such situations this may well mean that companies will need to undertake remedial work that- based on the DoE's definition of remediation- will involve a full site investigation and work to minimise the risk of causing significant harm to man or the environment or harm to a water resource. This can only increase the amount of remedial work being carried out and therefore increase the need for effective remedial measures.

8.5.3 #3: Prof Judith Denner

Occupation:	Head of the DoE Contaminated Land and Liabilities Division (CCLD) (Currently Head of Contaminated Land at the Environment Agency)
Organisation:	Department of the Environment
Date of Lecture:	24/January/1996

This account is based upon notes takes during a lecture given by Prof Judith Denner in her capacity as visiting Professor, upon questions asked during and after the lecture, Selected DoE policy guidance reports and private correspondence between the author and the DoE.

In order to encourage clarity the Government encourages it's Departments to keep their number of policy objectives to a minimum. Consequently, the CCLD has two primary policy objectives that are to:

1. remove unacceptable actual or potential risks to health or the environment, and

2. bring contaminated land back into beneficial use by the most appropriate and cost-effective means.

With reference to these objectives Prof. Denner made the point that the "crusade type approach" to remediating contaminated land is not realistic. Similarly, you cannot expect mulitfunctionality as in many cases it is not technically feasible or prohibitively expensive. The DoE advocate a phased or prioritised programme that observes the concept of sustainable development. This entails a balance between cost effectiveness and the recognition of external or environmental costs.

Government policy is laid out in the document "Framework for Contaminated Land" or "Framework" as it is commonly referred to. It states:

> Within this framework the Government's further objectives are:
>
> - to improve sites as and when hazards need to be dealt with, the private sector decides to develop land, or public bodies prepare land to promote development;
>
> - to encourage an efficient market in land which may have been contaminated;

- to encourage the development of such land; and

- to remove unnecessary financial and regulatory burdens (DoE 1994a).

It would be neither feasible nor sensible to try to deal with all land contaminated by past activities at once - the wealth creating sectors of the economy could not afford to do so. The urgent and real problems should be dealt with, but in an orderly and controlled fashion so that the economy, businesses, and land owners can cope.

Prof. Denner made the point that only in the past 5 years have the problems of contaminated land come to the fore in the United Kingdom.

> Question: Do you think that the United Kingdom, in terms of the development of contaminated land policy, can be considered unlucky not to have experienced an event such as Love Canal or Lekkerkerk?

Prof. Denner agreed with the question and in the ensuing discussion a concept of policy maturity was discussed. Immature policies are commonly implemented after a disaster. e.g. the restrictive legislative regimes introduced under Superfund and the Dutch mulitfunctionality approach. Prof. Denner contends that the United Kingdom has been lucky in the sense that this immature stage of policy development has been largely avoided. Prof. Denner stated that the United Kingdom did have the Loscoe incident but that this event has not had an important role in the development of policy in the United Kingdom. She considers the most likely stimuli to be general concern about old landfills; the recognition that contaminated land does cause problems in other countries; and the need to redevelop derelict industrial sites that were increasing in number due to industrial decline. Consequently, she feels that the United Kingdom has avoided much of the problems associated with immature contaminated land policy and has come to the more mature second level of strategic redevelopment and land use. Dr Denner considers the United Kingdom to be "up to speed in relation to the redevelopment of contaminated land".

Prof. Denner considers the one policy failure that has occurred to be the Section 143 Registers. However, she considers this as only a minor failure as it was of a political rather than a financial nature. One reason ventured for its failure was the coincidence of its introduction and a general election. Prof. Denner contends that the government bowed to pressure from industry over the potential for land blight. The argument against the Registers was that by introducing a register for *potentially* contaminated land, clean land would be devalued. The property and financial industries lobbied government contending that the United Kingdom economy is very much based on property values and that economic development is closely linked to property development. This argument found favour as the planning and redevelopment process had been recognised as

an important aspect in the process of economic growth for many years. The threat to the redevelopment process was therefore taken very seriously and the Registers were dropped.

> Question: You stated that there is a logical balance to be drawn between considerations of quality of life and the need for economic growth. Doesn't the concept of sustainable development imply growth in an environmentally benign manner and isn't the need for the development of high technology, such as remedial technology, an important goal. Consequently, why doesn't the Government use economic incentives to stimulate the development of remedial techniques and couldn't they offer similar schemes as can be found in the United States and Belgium where much of the red tape involved in testing new techniques is deliberately waved in order to stimulate the development of such technology?

Prof. Denner stated that one should take care not to attempt to "cherry pick" policy solutions. When conducting international comparisons she stated that it is of fundamental importance to assess the policy framework in place. Other important aspects included how projects are funded; the different approaches to risk assessment; the application of technology; the provisions of private law; and the administrative regimes in question. Prof. Denner described how, although the policy approaches of the United Kingdom and The Netherlands may appear to be radically different, they are converging. The Dutch system she described as having a "moral standing modified with pragmatism" that, she said, is limited by technical feasibility. She described the United Kingdom system as inherently pragmatic with room for voluntary improvement over and above what is required by law. This planning/development led policy is strongly supported by a drive for redevelopment.

In addressing this question Prof. Denner referred back to the Section 143 Registers. She stated that, with hindsight, it can be seen that the Registers did not conform with Department's overall environmental policy objectives. In contrast, the decision to go for the more mature policy of *suitable for use* is a result of an overall policy framework laid out in "Framework" and in the White Paper "This Common Inheritance". The objectives are to prevent new contamination occurring while dealing with existing problems in a pragmatic manner. Framework states that:

> the Government is committed to sustainable development and the polluter pays principle. The first priority is to prevent or minimise further pollution of this kind (DoE 1994a).

There is already an established, modern and effective regime for action, including criminal sanctions, to deal with future pollution on a precautionary and preventative basis.

The Environmental Protection Act 1990 and The Water Acts of 1990 and 1991 that established and enabled HMIP and the NRA are a logical progression of existing land use legislation. Legislation that was extensively

reworked in the 1970s. Prof. Denner disputes criticism that the United Kingdom has been slow to develop an environmental policy and contends that strong planning law has enabled the United Kingdom to quickly come up to speed.

Prof. Denner contends that the basis for the legislation has always existed. The planning law has zoning systems that have been effective for landfill and to a certain extent in relation to contaminated land. These systems allow the development of contaminated land to be an extension of the planning system. *Suitable for use* is seen as the philosophical extension of this system. It is a system that requires local authorities to make strategic plans to deal with contaminated land in a similar way to the planning development system. The need for prioritisation is another similarity.

Against this background, Prof. Denner pointed out that the Government is concentrating on the redevelopment of contaminated and derelict land by deregulating the market for its development. Consequently, the Government is unwilling to impose excessive restrictions on industry such as requiring the use of costly and largely unproved techniques. Such an approach is considered at odds with prescriptive technological requirements. Prof. Denner does not consider many treatment techniques to be ready for wide scale commercial use and the DoE concentrate on the validation of technology and not its development. The latter is the responsibility of science research councils, projects such as Challenge-Foresight Development and the NATO/CCMS study.

Prof. Denner stated that economic incentives specifically aimed at the encouragement of innovative technology had been considered and that the Landfill Tax is an example of this kind of measure. She emphasised that as such it is a radical policy considering economic incentives are rarely used in the United Kingdom and the policy objectives detailed above. In addition she stated that economic incentives are only considered if there can be a net gain from their introduction. In the case of contaminated land economic incentives were not considered suitable as stimulating the use of remedial measures was considered too expensive despite the potential for the development of new remedial technologies. Prof. Denner does not consider the United Kingdom to be as advanced in the development of innovative technology as other countries but this is due to our late recognition of the problem. The government is also reluctant to offer any form of tax break to industry and economic incentives are not widely used by any other departments. She thinks it may be a few years until economic incentives specifically targeted at innovative techniques could have the desired effect.

However, Prof. Denner then referred to the drive for the redevelopment of inner cities and derelict land as a form of EI that stimulates the market for remediation generally. She referred to Michael Heseltine as the champion of redevelopment securing £200m p/a for redevelopment through Derelict Land Grants and English Partnerships. She stated that although the scheme was not originally intended to deal specifically with

contaminated land it does so because it is precisely those areas of dereliction that have resulted from industrial decline that are contaminated.

> Question: How does the department intend to ensure a consistent approach by local Authorities considering that no extra cash is to be allocated to provide staff to deal with the new provisions and carry out investigations. In addition to what extent are local authorities to receive instruction in carrying out their duties?

Prof. Denner did concede that Local Authorities are to receive no money to employ more staff to carry out the functions the Act requires of them. Indeed all the functions required are to be accomplished out of Local Authority's existing budgets. She suggested that reallocation or reprioritisation was the answer and that staff could be moved from other environmental departments where there has been a downturn in the amount of work required.

> Question: Recent discussions with insurance brokers has revealed that there is ignorance about the problems of contaminated land amongst Small and Medium Sized Enterprises (SMEs). Is the £15m that can be allocated in the form of Supplementary Credit Approvals (SCAs) for the use of these SMEs where financial hardship can be shown?

Prof. Denner stated that the DoE can allocate and up to £15m p/a for local authority SCAs. These grants will be available for both home owners and SMEs where financial hardship can be demonstrated.

8.5.4 #4: Dr Mary Harris

Occupation:	Section Manager, Environmental Management Services
Organisation:	Clayton Environmental Consultants Limited, Birmingham, United Kingdom
Date of Interview:	31/January/1996

The following account was produced after a meeting with, and subsequent revisions by, Dr Mary Harris. The interview was conducted at the offices of Clayton Environmental Consultants Ltd, Birmingham, United Kingdom.

The United Kingdom's approach to the regulation of contaminated land developed out of the land use planning system and public health provisions.

I think what I was trying to say was that in the past, contaminated land was mainly regarded as a "redevelopment issue" and therefore part of the land use planning process. s143 (because it would have involved identifying both past and present contaminative uses) would have focused attention on operational as well as derelict or development land. At the same time as s143 was being proposed, the Water Resources Act 1991 was highlighting the importance of the water environment. The overall effect I think was to shift "contaminated land" away from being predominantly a "development issue" to being an "environmental issue" in its broader sense. There were many other reasons why s143 was not acceptable - including the fact that the land could not be deregistered (even after it had been remediated) because the register was based on the land use history of the land, not its actual condition.

I see the actual position as follows. There is provision in the existing legislation (e.g. the Environmental Protection Act (EPA) 1990 and the Water Resources Act (WRA) 1991) to deal with contamination where there are breaches of the legislation (e.g. where contamination arises because of a failure to comply with an IPC Authorisation, or a condition of a Waste Management License). Contamination may also be handled through the process of redevelopment (in which case it becomes a planning issue). The provisions of the new legislation are intended to deal with contamination which presents a significant threat to health or the environment, which cannot by dealt with be existing legal controls (i.e. environmental protection legislation, planning legislation) or on a voluntary basis

Dr Harris contends that an effective balance needs to be found if greenfield development is to be kept under control. She stated that in the past when redevelopment has occurred it has tended to rely on traditional civil engineering solutions.

The fact that predominantly civil engineering methods tended to be used in the past was a natural progression from dealing, for example, with the poor physical conditions of derelict land. It is possible that the chemical characteristics of the material being handled were overlooked. Even now, we need to be careful to ensure all the necessary disciplines are involved in managing contaminated land. Some of your text appears to suggest that contaminated land is a civil engineering issue - it may also involve biological and chemical engineering expertise!

She also believes, however, that as awareness of the problems associated with land and more importantly groundwater contamination increases then the need for more treatment techniques will also increase. Dr Harris made the point that the need to deal with effects on water will be one of the main reasons for the use of new technologies. Also it is difficult to excavate covers where operational sites are involved.

Dr Harris believes that because sub-surface conditions are essentially heterogeneous and, particularly in the case of industrial sites with long histories, so complex that in-situ remediation techniques are not widely applicable at present. In addition, ex-situ techniques are not able to deal effectively with such situations on the grounds of cost. i.e. because there is a limit to which you can physically remove material to depth.

In the United States a lot of money has been spent on developing treatment techniques. Dr Harris did say that the United States are faced with the fact that some sites will have to be contained, although, containment in the United States has been widely seen as a temporary measure, the primary objective always is total clean-up. She contends that in the United Kingdom properly designed containment is a viable solution in its own right. Note: the United States is increasingly recognising the need to redevelop brownfield sites and therefore faces the same problems as the United Kingdom.

Dr Harris sees soil washing as a viable remedial technique. It is ex-situ and may require a certain amount of waste transportation and landfill. However, she sees advantages in splitting waste into streams that can then be directed to either mobile or central processing facilities. Central processing facilities having the advantage that they can achieve economies of scale. However, there are drawbacks such as planning permission for such centres!

Dr Harris concedes that the price of landfill influences the selection of remedial techniques but that its influence is not clear cut. The provision of landfill is complicated by licensing and prices are volatile locally and over time and the changes concerning the Landfill Tax.

Increasingly an important aspect of the environmental and geotechnical engineering field is quality assurance (QA). Treatment techniques face problems in terms of QA in that in some cases the end point can be difficult to predict. Liability can be removed by removing contamination from a site, this in part explains the popularity of landfill. If it cannot be certain that a treatment technique removes the possibility of environmental liability this represents a barrier to the success of the technique. In addition, she contends it is difficult for some techniques to guarantee that it will work at all.

As most contaminated sites have to be treated on a case by case basis tests need to be carried out to ascertain how well if at all a technique will work in a specific situation. This then is a further barrier to the use of treatment techniques. In a similar manner to the way that site investigation is often cut back the process of testing a technique that may not be suitable for the job is considered to represent an additional unwanted cost.

Risk assessment is an important aspect of the *suitable for use* approach. However, Dr Harris thinks that for risk assessment to be carried out efficiently it must be carried out by specialists.

I think we need to be very careful here. Risk assessment is an important tool but it does need to be used with care. It is possible to produce generic guidance on risk assessment which is applicable in a wide variety of situations. This is essentially what is done when generic guideline values are produced to show the point at which particular concentrations of contaminants in soils may be a cause of concern under specific circumstances. However these values are developed using assumptions about the characteristics of sources, pathways and receptors. The onus is on the user to be clear that these assumptions apply in the situation being assessed. It is possible that site - specific conditions are such that generic values are not applicable (i.e. they may be overly protective) but the option exists for the user to demonstrate that this is the case. In practice this is where a very good understanding of risk assessment is likely to be needed. It is unlikely that the United Kingdom will introduce prescriptive guidance in the sense you imply. There will be a recommended generic approach and, if users wish to depart from this, they will have to be prepared to justify their actions on technical grounds.

Question: If new legislation such as the Section 143 Registers cause problems how can new regulations be introduces successfully without friction. Do you think policy makers will always be at the mercy of the most powerful lobbies?

I think it is inevitable that friction arises where there is a cost implication associated with environmental protection or improvement. At the end of the day, it is government ministers who have to decide the balance between the interests of different sections of society, and the policy position will reflect that balance.

QUESTIONNAIRE RESPONSE

1. **Question.** Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

I think both representations contain an element of truth. I would say Figure 1 represents the classical understanding of the process and Figure 2 the process as it might be in the future. Possibly Figure 2 shows the "market" (industry, suppliers of goods and services, consumers etc.) pushing to find technical solutions in parallel with the basic framework provided by policy and law?

In practice, I feel the effectiveness of either of the two systems in motivating technology development relies on the priority given to environmental improvement. In Figure 1, unless policy and law provides effective sanctions against environmentally irresponsible behaviour, and rewards for good practice, there is no incentive to move forward. In Figure 2, unless industrial practice is forced to innovate (in part by policy and law, in part by consumers and other sections of the market) then there will be no progress.

2. **Question.** In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques?

Technical uncertainty about the likely performance of innovative techniques is clearly a barrier. Overcoming uncertainty involves costs (e.g. treatability testing) that may not be acceptable in any individual case. Administrative uncertainty may also be an issue - for example, if it is not clear how an innovative technology is to be "authorised" under pollution control requirements; if it is not clear how work involving innovative technologies is to be specified or handled for contractual purposes; if there is a lack of familiarity or conviction on the part of clients, regulators, consultants etc. that the technique will "work".

3. **Question.** In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

Independent verification of the performance of a technology (e.g. under USEPA Site Programme) appears to have helped technology vendors to apply their techniques on a commercial basis.

4. **Question.** How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

Some form of field-scale demonstration programme with wide dissemination of results seems to be one of the most obvious ways. However, such a programme has to be well funded, well thought out and based on a rigorous scientific approach.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

The issue of public funding for scientific advancement is hardly a new concept! The point surely is to ensure that any such funding clearly results in a public benefit, i.e. a reduction the cost that the public might otherwise have to Pay in tackling contaminated land.

6. **Question.** In what direction is contaminated land policy moving

Definitely an emerging consensus internationally on the most appropriate technical approach. Probably a recognition on all sides that we are unlikely ever to be able to afford to bring land back to its pre - industrial condition. Probably still some debate to be had (at international level) on the most equitable way of apportioning the costs of environmental improvement.

7. **Question.** How will the global market for treatment techniques develop in the future?

Cost is going to be a limiting factor for all countries and prioritisation is probably inevitable, i.e. each country will have to target its resources on those sites / land which are presenting the most significant health / environmental risks. The most successful remedial techniques will be those which have the characteristics outlined below

8. **Question.** What types of remedial techniques will be successful...

...and what characteristics will they have?

8.a, Engineering - based techniques including "active" barriers e.g. where there is some provision for degrading / filtering/ modifying contaminants.

Ex-situ based techniques such as soil washing, which have a wide applicability and a potential for inclusion of modules designed to treat specific parts of the waste stream.

In-situ based techniques that can be used on operational sites to treat sources of groundwater contamination. Probably includes biological enhancement, air sparging etc.

8,b, Applicability to wide range of different contaminants.

Low capital, operation and maintenance costs.

Demonstrable reliability under a range of different conditions.

9. **Question.** What are the most pressing threats and opportunities facing the vendors and developers of innovative techniques for the remedial treatment of contaminated land?

One of the main threats is the perception that the remediation of contaminated land is unaffordable, unreliable and technically uncertain, or cannot be integrated within normal commercial activities.

One of the main opportunities is the greater awareness of the issue and a more general willingness to look at alternatives to conventional engineering based techniques, provided such alternatives can meet specific requirements.

8.5.5 #5: Phil Crowcroft

Occupation:	Director
Organisation:	Aspinwall & Company
Date of Interview:	12/March/1996

The following account was produced after a meeting with Phil Crowcroft of Aspinwall & Company at their offices in Shrewsbury. In addition, it draws on a papers written by Mr Crowcroft (Crowcroft 1992; Crowcroft 1995).

There was a superficial view in the late 1980s that a boom in the use of remedial technology was imminent. There were high environmental expectations, i.e. the predominance of green thinking. Subsequently, however, the economy went bust and the markets for many innovative techniques disappeared.

The Glory Hole incident in Portsmouth could be considered the United Kingdom's equivalent of the Love Canal but, curiously there was no great public outcry. It illustrated that an event will stimulate the use of remedial techniques and can attract the attention of local authorities but only a local level. He stated that contaminated land problems have the tendency to stay localised in the United Kingdom. There have been a variety of investigative incidents but nothing has come of them.

The civil law and regulation is weak. There will be no comprehensive register of contaminated sites in this country. Section 57 will not draw in a large number of sites as the majority of sites requiring remedial action will be cleaned up voluntarily and will therefore not be placed on the register. Cambridge water emphasises this point. Here was a situation where an aquifer was polluted by PCE and TCE and the polluter has not been made to pay. Section 57 may have the effect of encouraging the pre-emptive clean-up of land.

If there is an area where new techniques will emerge relatively easily it will be where there is a cross over from other industries. He cited the example of Prestige Air and stated that their example illustrates the problems faced by the providers of treatment techniques. Prestige Air operate a process for the emergency remedial treatment of radon gas in buildings. Radon enters building due to the pressure difference found between the soil gas in the ground and the atmospheric pressure in buildings. This pressure difference means the Radon gas migrates preferentially into houses. The technique of increasing the air pressure in buildings, and so preventing the ingress of gas, was adapted for the use in situations where gasses released from hydrocarbon spills became threatening. This technique has been reasonably successful. However, when they

attempted to adapt the techniques to testing landfill liner integrity they had less success. Mr Crowcroft proposed that this was because regulation is weak in the United Kingdom and that there is infrequent requirement to rigorously test landfill. He considered it telling that a market can be found for an emergency remedial measure but not for a preventative technique.

Mr Crowcroft contends that current contaminated land legislation is inherently weak. A comparison was made with the COPA that although weak by modern standards failed primarily because of poor enforcement rather than through any lack of legislative power. He contends that although the NRA and the EA have powers they will not be fully enforced. The result will be that developers will wait and see what are the minimum requirements and this will dictate the level of compliance in the country. A level of compliance that will inevitably fall short of the levels expected by law. The reason the enforcement agencies will not be able to carry out their role fully is because there will not be the money to carry out the remedial works that could be legally carried out as the agencies do not wish to become involved in the legal battles that would, they feel, follow. There is a reluctance to follow the Superfund route of chasing polluters through the courts for the costs of clean-up.

Mr Crowcroft successfully predicted that contaminated soil would be exempt from the Landfill Tax. He believes that the costs of landfill still do not reflect their true costs and that they represent a fundamental barrier to the entry of new techniques to the market.

He pointed out a promising area of active containment that can compete with landfill as it retains contaminants on site. It relies on the long term disposal of contaminants but unlike landfill some effort is made to remediate the contaminants present. Envirotreat are working on such systems. They may have a future but only for long term remediation projects. Another promising technique is soil washing. At present its costs, in some situations, are comparable with landfill. He told of a situation where soil washing was used to clean dredged soil. The fact that the soil was wet made the washing process economic. Even in this case some by-products had to be landfilled.

In a discussion concerning the changes that have occurred in the field between 1991, when Mr Crowcroft authored "Innovative Clean-up Technology - The Barriers to Implementation" and the publication of "Remedial Techniques - Achieving Solutions Which Satisfy all Parties" in 1995, he stated that there has been little change. Despite the opinions of those members of the industry Mr Crowcroft referred to as "Doom-mongers" he sees little change. Legislation has tightened somewhat, although the NRA has had little effect as proof of groundwater- as opposed to surface water pollution- is notoriously hard to come by. The Banks have not changed their position. They are still not comfortable with sites that may entail long tail liabilities and public awareness has had little effect in terms of contaminated land. It is not a popular subject.

A further observation is that redevelopment is not considered as profitable as it was once thought. He stated that development companies have been "catching colds" implying that some have begun to back away from the development of brownfield sites.

When asked if he thinks this paints a very bleak picture for the industry Mr Crowcroft was more upbeat. He did not agree with the assumption that there is not a market for treatment techniques, rather he described an "industry in waiting". At the present time he sees a situation where even the landfill market is struggling and, in an attempt to cover fixed costs, some landfill operators are having to take waste at a loss. In addition the landfill industry see treatment techniques as a competitive threat, so much so that operators are actively cutting costs to undercut some remedial techniques.

Mr Crowcroft estimates that at present there are only about 10-20 bio-remediation projects being carried out each year in the United Kingdom. Other techniques are very scarce with such techniques as thermal and vitrification works only accounting for a few jobs per year between them. He considers the most popular technique to be slurry trench walling with an estimated 50 jobs per year, generally in heavily and complex contamination where remediation is difficult. However, this does not include vacuum extraction that is quite widespread for petrol removal.

(Reflective: The opinion that Section 57 may cause pre-emptive clean-up may be the case especially as contaminated soil is free from Landfill Tax while soil that is removed as a result of a remediation notice is not.

Redevelopment led remediation will not lend itself to the use of extensive techniques. However, quango type bodies may well be suited to the use of such techniques where long term programmes can be used.)

Questionnaire Response

1. **Question.** Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

I think figure 2 [in the Questionnaire] is closer to reality but would suggest that cost should figure as a driving force, and that new techniques are really part of geotechnique, see Figure 1.

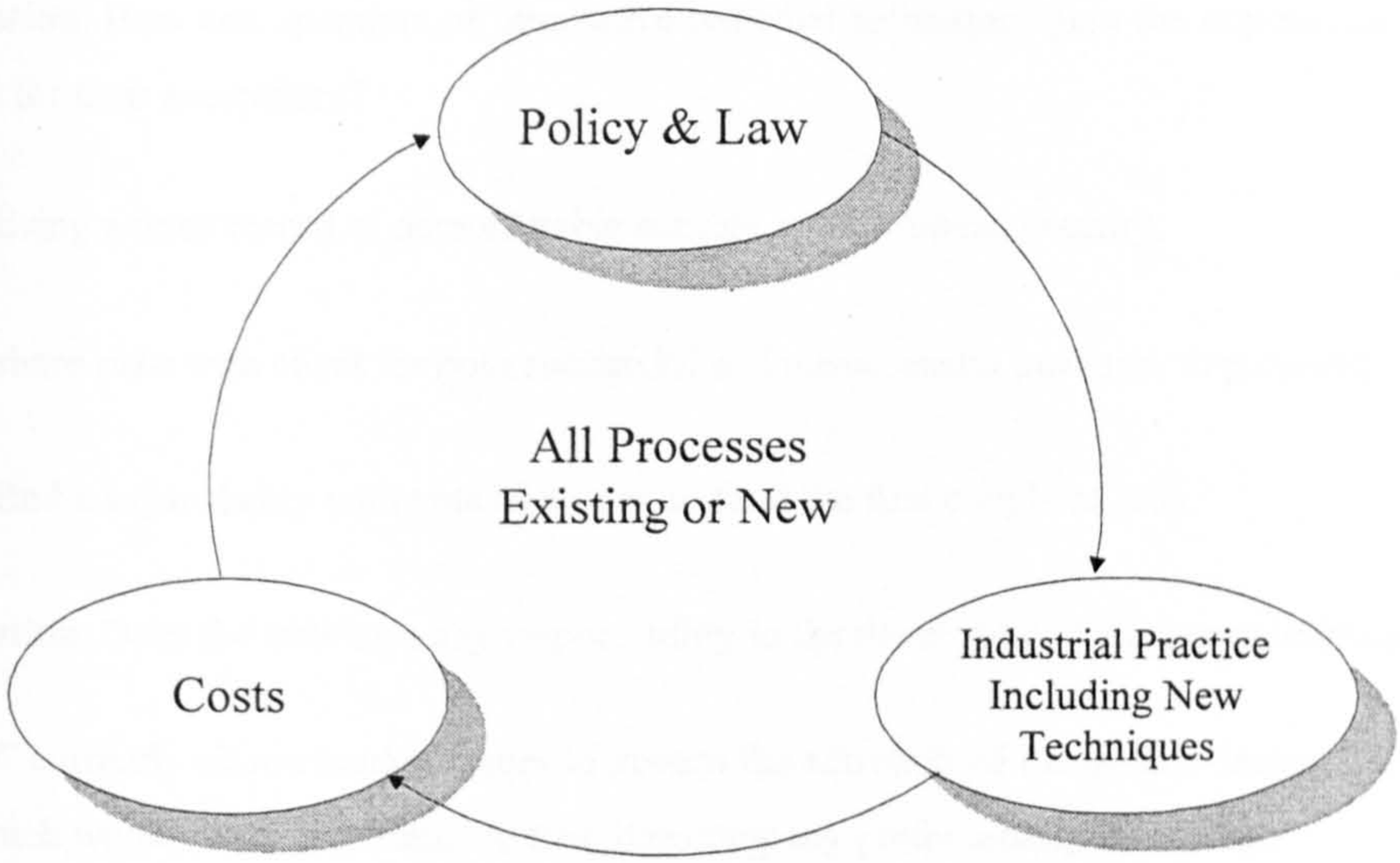


Figure 1: Crowcroft's Proposed Model for the Dynamics of Innovation.

2. **Question.** In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques?

Uncertainty with respect to:

- whether contamination has to be destroyed to make it safe, or whether secure contamination is acceptable;
- who decides what is acceptable (EA, planning authority, future EC Law etc.);
- Out-turn costs of using a particular treatment; and
- confidence in quality of end product.

3. **Question.** In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

- by using the technique and demonstrating its success. i.e. vacuum extraction, positive pressure air systems;
- by convincing a client that he must look at a new techniques for the future on the basis that landfill disposal will not always be cheap or readily available.

4. **Question.** How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

- Bring a track record of demonstrable success in a European country;
- share risks with client for both successful and unsuccessful out-turns to projects;
- find a sugar-daddy with pots of money to fund the first couple of jobs.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

No. the "state" currently allows market forces to govern the activities of the private sector. I am not aware of any statute which would cause the "state" to treat one company preferentially to another.

6. **Question.** In what direction is contaminated land policy moving?

- Decisions on the need for cleanup will be risk based;
- *Suitable for use* now appears to be coming in Holland/United States, so we are unlikely to change from this ourselves.

7. **Question.** How will the global market for treatment techniques develop in the future?

More likely to develop quickly in mainland Europe and North America due to high cost of landfill. South East Asia has little or no potential currently due to low standards of landfill, or in the case of Hong Kong, free landfill! If a technique is cheaper than landfill, and is proven effective, then it has an assured market.

8. **Question.** What types of remedial techniques will be successful...

...and what characteristics will they have?

8,a,

- biosparging,
- positive air pressure,
- techniques to eliminate leachability, and
- active containment walls.

8,b,

- low cost;
- high degree of effectiveness;
- dealing with mobile contaminates which have got below buildings;
- flexible in terms of method of application; and
- not requiring permitting.

9. **Question.** What are the most pressing threats and opportunities facing the vendors and developers of innovative techniques for the remedial treatment of contaminated land?

Threats:

- exemption of contaminated soil from Landfill Tax;
- continued undercosting of landfill; and
- conservative approach to funding institutions.

Opportunities:

- increased industry awareness of contamination issues.

8.5.6 #6: Kelvin Potter

Occupation:	Environmental Consultant
Organisation:	ICI Engineering Technology
Date of Interview:	4/April/1996

This account is based upon notes taken during an interview with Mr Kelvin Potter. Reference is also made to IMS10 (Potter et al. 1994). It was conducted at ICI's offices in Runcorn, Cheshire, United Kingdom.

Mr Potter emphasised at the outset that he was speaking in his capacity as an IMS project leader, see below, as not as an ICI employee. The opinions expressed do not necessarily reflect opinion within ICI.

Mr Potter described how ICI first began to take note of the problems associated with contaminated land when the Love Canal incident received widespread recognition. This was in 1980 and coincides- though not coincidentally- with the promulgation of Superfund. He contends that even though the problems associated with the Love Canal were an overreaction it alerted ICI and most other large international corporations to the potential problems associated with contaminated land. It was discussed how it appears the Love Canal incident has entered the folk culture of the United States, illustrating an inclination towards overreaction as opposed to the more pragmatic approach taken in the United Kingdom.

Mr Potter described how many firms in the United States became fearful that standards would become unrealistically onerous and applied retrospectively, possibly resulting in the major remediation of contaminate land. This illustrates the reaction to the Superfund legislation that is taken to be the perfect example of overtly stringent legislation causing a negative reaction by industry. Mr Potter considers the amount of money spent to date on contaminated land problems to be excessive. He referred to an Australian article that estimated the cost of preventing death due to a ban on the disposal of hazardous waste to landfill was $4 billion as opposed to $0.1 million for car seat belt standards ($US). He suggested that it is difficult to get the problems associated with contaminated land into perspective. He suggests it is an emotive though little understood issue. The risks involved not being widely known or understood.

In the United States there is a growing realisation that their system for dealing with serious contamination has problems. Consequently, there are moves afoot to move towards a more pragmatic approach. However, Mr Potter does perceive a problem in the regulatory culture in the United States.

Mr Potter described how in 1989 Japan's Ministry of International Trade and Industry (MITI) invited United States and European Union companies to co-operate in research and development in advanced manufacturing with the aim of reducing common areas of uncertainty and concern. IMS10, "A Structured Approach to Remediating Contaminated Land", was one pilot study in this initiative funded by ICI and the European Commission. The Study had two main aims:

- to identify factors which influence the way in which remediation options are selected and assess whether it is possible to rationalise the process and

- to identify common areas of concern and uncertainty about remediation which have the potential to be resolved by international collaborative research and development, e.g. through future IMS projects.

These aims were driven by a belief that despite the fact that a great deal of money had been spent world wide remediating contaminated land the bulk of such remediation involved the use of low technology methods. The report attempts to determine "whether this represents money well spent on the most appropriate solution or if it is indicative of the dominance on non-technical influences in the decision making process". In addition it asks "whether current research and development programmes are addressing the real needs and concerns of those dealing with contaminated land".

Mr Potter provided some details of the Network for Industrially Contaminated Land in Europe (NICOLE). NICOLE was created in February 1996 and is a programme sponsored by DGXII of the European Commission. It is an industry led initiative the aims of which are to disseminated scientific and technological information concerning contaminated land and groundwater, to promote multidisciplinary work and inform planners of National and European research programmes of the needs of industry. The initiative is supported by ICI though it is not a direct outcome of the IMS10 project. It does, however, attempt to come to terms with some of the recommendations made by IMS10. It is an attempt by industry to understand the nature of the common problems they face and is an attempt to alert research institutions of these important areas.

Questionnaire Response

1. **Question.** Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

In a highly prescriptive regulatory environment where cleanup standards are becoming increasingly onerous, the focus is on developing cleanup technologies which can achieve the specified cleanup criteria in the required time frame. This means improving existing technologies or developing new techniques. Cost becomes important if there are competitor technologies.

In a more pragmatic environment where cleanup criteria are derived by risk assessment, the focus for technology development is to look for a step change in cost, or to solve problems where because of the scale of the problem, the cost of existing techniques is prohibitive. The process of technology selection is also influenced by other factors such as corporate preference, public opinion, etc..

2. & 3. **Question.** In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques? **Question.** In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

Biotreatment is a classic example. Early promoters of this technology made wild claims about its capabilities, some alluding to it as a panacea. Early lack of success set back this technology. Fortunately, it is now being applied in a pragmatic way and achieving success.

4. **Question.** How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

- Establish confidence in the technique by rigorous laboratory testing and small scale field trials;
- participate in schemes like the United States SITE programme;
- submit proposals to national and international R & D funders;
- set up demonstrations partly funded by vendor and by interested parties which if successful will lead to full scale field testing; and
- lobby organisations such as SAGTA in the United Kingdom for support.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

This is a political question and goes beyond my sphere of specialist knowledge. Intuitively I would suggest the answer is no other than not to create an economic environment where innovators are handicapped. Developing treatment techniques is a risky business and those embarking on such a venture should do so with their eyes open.

6. **Question.** In what direction is contaminated land policy moving?

Internationally, undoubtedly towards a risk based approach in which a site is cleaned up so that it is fit for its purpose.

Regulators will increasingly accept reasonable time frames for achieving cleanup.

7. **Question.** How will the global market for treatment techniques develop in the future?

A marketing question. My crystal ball is no better than anyone else's. I would suggest that the predictions of economic expenditure on cleanups will not materialise, partly as a result of proper assessment of the significance to health and the environment of contaminated land, and partly as a result of contaminated land issues maintaining a low public profile.

8. **Question.** What types of remedial techniques will be successful...

...and what characteristics will they have?

8,a,

The innovative remedial techniques that are likely to be successful:

- Natural attenuation (intrinsic bioremediation) of organic compounds in groundwater;
- in-situ biotreatment (soil and groundwater); and
- active containment methods. e.g. permeable treatment walls, funnel and gate (especially zero valent iron for chlorinated hydrocarbons), sir sparging curtain walls, in well stripping e.g. Novice's technology.

8,b.

- Relatively easy installation;
- low cost (taking into account installation and O/H costs);
- low maintenance requirements; and
- protracted time scale to achieve cleanup.

9. **Question.** What are the most pressing threats and opportunities facing the vendors and developers of innovative techniques for the remedial treatment of contaminated land?

Threats:

- Potential market size shrinking once the true risks associated with contaminated land are assessed and recognised;

- not being able to install full scale installations and obtain a track record;
- not being able to produce a technique at a competitive price;
- producing a technique which is unacceptable for reasons other that effectiveness or cost. e.g. vitrification and NIMBY; and
- the long period required for a new technique to achieve acceptance in the market place and with regulatory authorities.

Opportunities:

- schemes such as Clean Sites, RTDF and SITE programme in United States;
- European Union funding; and
- niche market.

8.5.7 #7: Neil McLeod

Occupation:	Technical Director
Organisation:	Envirotreat Ltd, West Midlands, United Kingdom.
Date of Interview:	10/May/1996

The following account was produced after a meeting with Mr Neil McLeod of Envirotreat Ltd at their offices in the West Midlands, United Kingdom.

Envirotreat have developed a chemical stabilisation technique in association with Birmingham University and May Gurney Ltd. They are currently working on the use of modified slurry trench walls for active containment.

Mr McLeod considers that much of the optimism has gone from the United Kingdom remediation market. As an example of a trend amongst consultancies to cut back on their contaminated land provision he cited the decision by Miller Environmental to close its contaminated land division. Miller Environmental moved into contaminated land at a time when massive booms in remedial action was predicted. He contends that firms started in the late 1980s and early 1990s are finding it difficult to find work. A common mistake is that many firms have been expecting the Landfill Tax to solve the problems they are having attempting to compete with landfill. He considers it dangerous to rely on legislation to create your market as can be seen through the failure of the Section 143 Registers, the recent decision on the Landfill Tax and the lack of speed at which the guidance that adds detail to government policy is published.

Mr McLeod contends the Section 143 Registers were stopped by powerful lobbying on behalf of property owners and developers. Mr McLeod still believes a complete register is required if contamination is to be successfully addressed. He contends that the failure of the Section 143 Registers needn't have happened if contaminated sites could have been removed once remedial action had occurred. In addition a register of potentially contaminative uses was a poor idea. He also believes that a register would stimulate a market for remediation.

When asked about the development of the chemical fixation technique Mr McLeod stated that initially he deliberately looked to the USEPA standards as benchmarks. The reason for this decision was that he considered that for the new technique to be accepted it must be demonstrable. Mr McLeod contends that it was this decision that helped secure Environmental Technology Innovation Scheme (ETIS) funding for their

role in the development of standards for in situ remediation. ETIS was a scheme organised by the DoE and DTI between 1990 and 1993. Envirotreat were the only company in the United Kingdom to be accepted onto the scheme. Mr McLeod considers it unlikely that they would have been successful without the funding and kudos afforded by ETIS.

Mr McLeod believes the reason for the lack of parity between the British and American Markets to be based on a difference in the way people react to environmental problems. He contends that in the United Kingdom the primary concern tends to be land values where there must be a direct effect for action to be taken over contamination. By contrast the United States and Australia can afford to take a more moralistic attitude because their industry is spread out, relatively more recent and contamination is easier to trace back to its producer. He considers the market for contaminated land to be strongest in America because they were the first to experience real problems due to poor planning but also because the sources of contamination are easier to define.

It is for this reason that Mr McLeod considers Superfund to be the mainstay of the contaminated land industry. The United States market is meeting maturity and much of the innovation in the industry has occurred in this market. In comparison few United Kingdom firms develop their own technology. The majority of solutions offered are franchised from the United States or Europe. Mr McLeod considers the effect of the Landfill Tax will be to prevent the development of a United Kingdom remedial technique industry and move the United Kingdom towards the use of landfill as the primary solution to the contaminated land problem.

Mr McLeod stated that the United States cannot pull back from their stringent requirements for remediation as they have come too far. Although the United States may be moving towards a more risk based system there will always be the assumption that the goal is to clean-up sites not simply render them *suitable for use*. Here there is a contrast between the United States and Europe. Mr McLeod does not think it is too late for Europe to move to a more pragmatic approach. However, he thinks that Europe will concentrate on the Use of central processing facilities while the Americans concentrate on mobile facilities. When dealing with European customers he offers greater levels of protection than he would to a British client due to the more stringent European standards of protection.

Mr McLeod believes that Envirotreat cannot hope to compete with landfill on a cost per ton basis. While promoting the encapsulation technology between 1993-1994 a number of areas were mentioned many times during demonstrations. These were; Liability, Residual concentrations, government support and cost per ton. In addition contribution to the NATO/CCMS programme also heightens their awareness. It was realised that if Envirotreat were to be successful careful marketing must take place. An understanding of the market and the needs of developers led to the decision to develop active containment

Envirotreat's marketing strategy and research and development direction are dictated by a close analysis of the market for remedial techniques. Mr McLeod perceives a problem with remedial techniques to be that they are considered risky and that they don't add value. For this reason emphasis is placed on the unique benefits of remediation such as the removal of the need for monitoring. In relation to this Mr McLeod perceives a problem with contaminated land research that is academic research tends to be generic while industry deals with site specific situations.

The market for remedial techniques is considered difficult for a number of reasons. Firstly that landfill operators consider contaminated soil as a useful material because it not only provides profits but because it can be used to dilute more heavily contaminated material. Landfill operators are in a very competitive position in terms of price. For this reason Mr McLeod considers that many techniques will only be able to function in specific niches, for example, he considers bio-remediation may be restricted to cleaning petroleum contaminated sites.

Questionnaire Response

1. **Question.** Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

General agree with the basic principle (albeit somewhat simplistic).

2. & 3. **Question.** In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques? **Question.** In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

We did not experience major problems in this area as we developed our technology with a clearly focused technology approach based on advancement of existing conventional stabilisation technology. The technology approach was supported by the DoE through the ETIS scheme where we had to demonstrate that the technology approach was a, technically innovative, and b, commercially viable.

4. **Question.** How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

Only by carrying out field scale testing and ideally by obtaining a track record. But this is a classic "catch 22" situation. Fortunately, out ETIS project enabled us to carry out a full site trial involving commercially applied plant and equipment. Otherwise it would have been very difficult to overcome this obstacle to commercialisation.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

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8.5.8 #8: Mark Dyer	
Occupation:	Director and technical advisor and co-ordinator for the EPSRC
Organisation:	Mark Dyer Associates
Date of Interview:	15/May/1996

The following account was produced after a meeting with Mr Mark Dyer of Mark Dyer Associates at their offices in Bristol, United Kingdom.

Mark did not agree with the dynamic model described and illustrated in the briefing document. He proposed the model in figure 1.

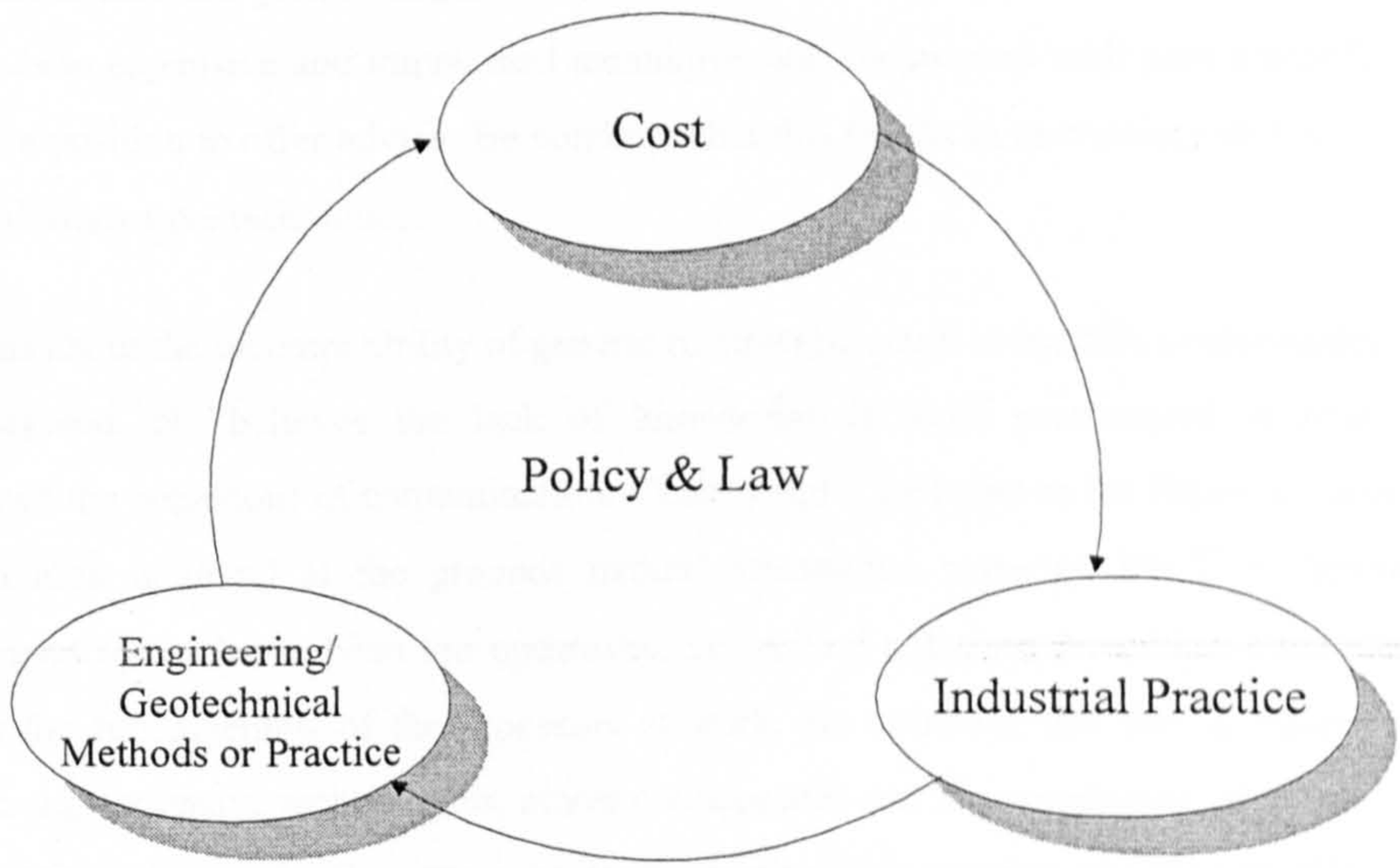

Figure 1: Dyer's Proposed Model for the Dynamics of Innovation.

Mr Dyer contends that although external factors, such as the public's concern for the environment, do influence the development of policy and law it is ultimately Governments that drive the promulgation of environmental laws. He contends that law is the primary influence on the development of new technology with other factors: cost; scientific knowledge; and engineering methods and processes interacting to influencing the dynamics of development.

Mr Dyer emphasised his point by disputing the argument that the United Kingdom government has been slow to act through a disregard for environmental standards or because of a reluctance to burden industry with excessive regulation. He contends the Government is aware of the problem of contaminated land and has been for many years and that the United Kingdom's planning and zoning laws have prevented major problems from occurring. Developing this theme he proposed that the reason the Netherlands have greater environmental awareness is related to the fragile nature of their environment and through necessity as opposed to a higher level of concern.

He believes that contaminated land regulation should be written with regard to commercial interests in order to make it compatible with the planning process. In addition, he believes the thrust of the new legislation is sensible as trigger levels are often rejected in favour of a more flexible risk based approach where the mobility and fate of contamination is considered more important that its mere presence.

Mr Dyer contends that the body of knowledge concerning land and groundwater contamination and its effect is inadequate to attempt to develop treatment techniques. This is because contaminated land remediation combines public health and ground engineering, two areas that are not traditionally associated. This lack of knowledge leads to expensive and impractical techniques and consultants with poor scientific understanding who are not in a position to offer advice. He contends that this results in uncertainty that prevents the use and development of innovative techniques.

When questions about the incompatibility of generic or strategic work to specific contaminated land problems Mr Dyer disagreed. He believes the lack of knowledge is most pronounced in relation to general understanding of the behaviour of contamination. Consequently he believes the future for contaminated land research is to look in detail at the grounds natural attenuation capacity. Mr Dyer believes that much contaminated land research has been too optimistic. i.e. radical solutions have been attempted without first understanding the fundamentals of the processes at work. He contends that this is where research is now being targeted. e.g. extensive technologies, active containment and bioremediation all depend on an in depth understanding of the ability of soil to attenuate contamination if they are to operate cost effectively. Mr Dyer thinks the United Kingdom is particularly strong in the area of generic or strategic work and that the United States are weak. e.g. treatment techniques being developed without an understanding of fundamental principles.

Mr Dyer was asked specifically about the lack of funding for the demonstration of developing remedial techniques at pilot scale. He contends that this is not the job of the research councils. He believes the research councils should carry out fundamental research, the DoE strategic and the EA applied. However, he also stated that research will not create a market.

Mr Dyer considers that uncertainty can occur in the relationships between clients, contractors and consultants. He stated that some clients will be aware of technical issues and be able to assess a contaminated land project and that this type of client will be involved in development on a regular basis. However, other clients may be looking for one off projects and have no experience and will therefore rely totally on the consulting engineer for advice. In these situations he considers it the responsibility of the consultant to produce something that works.

In relation to the growth in contaminated land consultancy in the United Kingdom Mr Dyer considers it easy for consultancies to operate, though not necessarily become established. In contrast he sees the requirement that contractors have designated plant as a major barrier to the development of treatment techniques due to the expense and risk involved in investments in an uncertain market.

(Reflective: It could be argued that the fundamental problem with the Superfund regime is an over estimation of the power of technology to provide immediate solutions and accurate assessments of risk at the expense of more pragmatic and albeit unsustainable alternatives.

Mr Dyer is saying without knowledge of the fundamentals one cannot attempt to solve problems as you do not know what the problems are.

It is true when Mr Dyer says that research cannot create a market where legislation does not encourage its use. The draft guidance issued to local authorities makes it clear that innovative techniques should not be selected for their own sake and that the most cost effective technique should always be used.

The impression given is that risk assessment, attenuation, monitoring and increased understanding of fundamental processes is where the research councils will be concentrating their efforts in a situation where advanced technological solutions are increasingly abandoned in favour of attenuation based methods.

QU-Considering the weak nature of the United Kingdom remedial technique market and the lack of incentives to develop new techniques is this reflected in the way funds are allocated.)

Questionnaire Response

1. **Question.** Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

Figure 2 is more realistic.

2. **Question.** In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques?

Lack of basic scientific knowledge and understanding about process.

3. **Question.** In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

Very little so far in the United Kingdom.

4. **Question.** How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

Invest in R&D to evaluate technologies.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

No.

6. **Question.** In what direction is contaminated land policy moving?

Transfer of liabilities to purchasers of land.

7. **Question.** How will the global market for treatment techniques develop in the future?

Increase markets accompanied by more competition for rudimentary techniques.

8. **Question.** What types of remedial techniques will be successful...

...and what characteristics will they have?

Bioremediation and natural processes.

9. **Question.** What are the most pressing threats and opportunities facing the vendors and developers of innovative techniques for the remedial treatment of contaminated land?

Low landfill costs in the United Kingdom.

8.5.9 #9: Ian Burbidge & Cameron M. Scott

Occupation:	Research Scientist and Managing Director of European Operations
Organisation:	Biotechna Environmental Limited (BEL)
Date of Interview:	3/June/1996

The following account was produced after a meeting with Mr Ian Burbidge and Mr Cameron Scott at their offices and laboratories in Dorking, Surrey.

BEL operate in three primary areas. These are: microalgal biotechnology; photosynthetic purification; and Graesser technologies. Biotechna-Graesser Limited is a wholly owned subsidiary of BEL, they deal in the ongoing development, licensing, leasing and selling of Graesser technology. The Graesser contactor comprises a series of rotating buckets within a cylinder that is filled with two liquid phases. It was originally designed to separate liquids with small density differences, low interfacial tensions and pronounced tendencies to form emulsions. It is a device commonly used in the chemicals industry to separate chemicals from waste for reuse. Recently Biotechna-Graesser have been working on applying the device to the remedial treatment of contaminated land.

Recently, new American owners have instigated a number of changes in an attempt to make the contaminated land applications more competitive. Mr Cameron described how the previous management team was not efficient. He stated that exaggerated claims were made concerning the abilities of the Graesser to treat contaminated soils. In addition, many samples were analysed for potential clients on a speculative basis but few leads were generated or followed as a result of this work. (Reflective: this illustrates an example of poor marketing. The Ends Report review of environmental consultancy made similar comments) The new management team have developed a questionnaire based system where a clients potential needs are analyses prior to any testing being carried out. It also illustrates a cautious approach towards the development of the Graesser as a remedial technique. An approach that mirrors the uncertain nature of the remediation market. As the Graesser already has an established market in the chemicals industry any further uses in the contaminated land industry are addressed on a case by case basis. Biotechna-Graesser are not actively working to assess how the technique can be applied to contaminated land. At the present they rely on clients to come to them and they then make an assessment of whether the idea is feasible.

Biotechna are in a unique position as the Graesser was developed in the late 1950s. The technique therefore has a proven track record. e.g. the Graesser is well known in the chemical industry. This high level of understanding instills confidence in potential clients. Consequently, the capabilities of the Graesser are slowly being assessed in relation to contaminated land. Assessment work comprises how best to apply the technique and whether it can be economically used in specific cases. For example the technique can be used to remove PCBs effectively. However, this requires extensive use of benzene, a substance that cannot be used for legal reasons. This is the type of problem that is solved on an ongoing, albeit gradual, basis.

Biotechna-Graesser do not operate as a remediation contractor. They sell or lease the units to the companies who are to operate them. However, Eurotec Soil Remediation Ltd currently lease two Graesser units mounted on flat bed trucks.

Without the increase in the use of integrated techniques the use of the Graesser in contaminated land would have been restricted. Increasingly, the technique is requested to form a part of an integrated approach to remediation.

Biotechna have had a positive experience of the DTI's JEMU project. As a result of the scheme a number of commercial officers from overseas, with responsibility for sourcing technology, were shown the Graesser. The demonstration took place in May 1996 so at time of the interview there has been little chance to evaluate the effectiveness of the initiative.

(Reflective: Questionnaires are a technique adopted by both Biotechna and Eco-Environmental in their approach to research and lead development.

Process integration means that the Graesser can be selected as a part of an integrated solution. To a certain extent this helps to solve some of the problems relating to the function of the process as the requirements placed upon individual components in an integrated system can be less demanding, requiring less intensive development in terms of their technique but also meaning that the approach has a greater chance of success as techniques can be allowed to operate within reasonable performance envelopes.)

8.5.10 #10: Gavin Costigan and Duncan Egerton	
Organisation:	DTI and JEMU
Date of Interview:	12/June/1996

The following account was produced following an interview with Mr Gavin Costigan and Mr Duncan Egerton at the DTI's offices in London.

The problems of the developing legislation were discussed. The process of internal consultation was outlined and proposed as a reason why it is difficult to produce laws on contaminated land.

It is true that internal consultation on contaminated land is a difficult exercise, but I would not say that that in itself was "a reason why" it is difficult to produce legislation on contaminated land. The consultation throws up the difficulties, which are numerous, including the one you have highlighted about risk analysis. Contaminated land policy has at its core the polluter pays principle, but designing laws which are fair and equitable is difficult, especially when it is difficult to define who the polluter is or (more often) how much of the pollution he/she has caused

Indeed previous cases have shown that even when environmental laws have undergone extensive internal review and gone out to consultation they can still fail. The Section 143 Registers are an example of this phenomena, in that it wasn't until the law reached its final reading that the CBI and the Landowners Association realised its implications and lobbied against its introduction. This was after an initial consultation period when they were made aware of the new measures. (Please note this is a personal opinion and should not be quoted as a Departmental position. Gavin Costigan)

Gavin identified uncertainty relating to environmental liability as a factor that limits the redevelopment of brownfield sites. In addition, environmental insurance is limited as companies respond cautiously to changing circumstances. A lot of this uncertainty will be removed when the provisions of Section 57 is enforced. The DoE will shortly be publishing a draft of the necessary Statutory Guidance for consultation is limited as companies respond cautiously to changing circumstances, but at any one time it is reasonably clear what is available.

(Reflective: This is therefore not only a legislative problem but a problem that includes diverse areas such as the development of a market for insurance. This insurance problem is occurring in parallel with the contaminated land problem. A problem largely caused in the United States thanks to stringent environmental standards and strict, retroactive joint and several liability.

Increasingly risk is becoming important in the development of policy.)

Questionnaire Response

All the following are personal opinions only.

1. **Question.** Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

As Duncan and I said when you met us, innovation is a complicated process with a number of factors. I have no doubt that these factors inter-relate, but I am somewhat wary of a simple diagrammatic representation of the process. For example, an individual company might innovate in response to a new law, but that law will not have been produced in isolation, it will depend upon an assessment by policy makers of what is, or may be, technically feasible, what can be delivered to solve a problem. Even understanding the problem may depend upon scientific knowledge or the latest available techniques. In this area, there will be several options for decision-makers to take at any one time, some of which will lead to a dead end rather than a cyclical process as you have indicated. Neither of the models really deals with this complexity; I cannot, however, offer an alternative that does.

Specifically considering your two models, I am not sure what the arrow between cost and scientific knowledge is supposed to mean in Figure 1 (it would be clearer to say "scientific research" or, as in Figure 2, "New Techniques"). Increased costs (and therefore reduced profits) may act as a spur to conduct or commission research to find new techniques or procedures which will relieve these costs - but only if the research is seen to be cost effective (this is an example of the "options" mentioned above). In Figure 2, the "external influence" arrow seems a little odd; I am not sure what it is supposed to mean.

5. **Question.** Does the state owe any responsibility to the developers of treatment techniques?

This is a very widely phrased question. The state has certain responsibilities to all companies, encapsulated in all kinds of law (company law, health and safety, customs and excise etc.). The DTI's overall objective is "to help United Kingdom business compete successfully at home, in the rest of Europe and throughout the world". It has a number of secondary objectives to meet this overall objective (see attached sheet), including taking the needs of business into account when developing its policy, helping United Kingdom business to take advantage of market opportunities, stimulating innovation and encouraging best practice. The DTI

sponsors the environment industry (including developers and manufacturers of treatment techniques) via the Joint Environmental Market Unit (JEMU).

Clearly the Government must balance the priorities of different departments, and the priorities within departments. Within DTI, action taken to benefit one industry sector may disadvantage another. It is the Government's job to balance these factors fairly in such a way as to meet its overall objectives.

6. **Question.** In what direction is contaminated land policy moving?

Policy in this area is based on the polluter pays principle, with restoration standards set at those suitable for current use. Section 57 of the 1995 Environment Act, soon to come into force, is based on those two principles, and formalises many of the liabilities which polluters have had for some time under common law (primarily under the torts of negligence and nuisance and the tort from *Rylands vs. Fletcher).* Any change in use may require restoration to a higher standard; this is dealt with through planning regulations.

Section 57 of the 1995 Environment Act, and the Statutory Guidance which DoE will shortly be releasing for consultation, shows the latest Government position on restoration of contaminated land. Local Authorities are to assess which land in their respective areas are contaminated, and serve remediation notices on polluters or "knowing permitters". Where these cannot be found, liability can pass to owners and occupiers of land. There are measures for deciding and allocating liability, and hardship measures for those who might be unable to meet their commitments.

The Act defines "contaminated land" for the first time, where significant harm or pollution of controlled waters is actually taking place, or when there is a significant possibility that such harm or pollution will occur. Deciding what constitutes a significant risk is based on pollutant linkages (there must be a source of potential pollutant, a receptor which can be polluted, and a pathway from one to the other which the pollutant could follow). Knowledge of the potential harm of substances increases all the time, and so future liability will depend on knowledge at the time. However, as liability is retrospective under the legislation, "pollution" considered harmless today could require clean-up at a later date if it subsequently discovered to be harmful. The assessment of harm may include the precautionary principle (i.e., whilst an assessment of the potential effect should be based on sound science, the absence of conclusive scientific data should not be a bar to judging something to be "harmful" in certain quantities if there is sufficient scientific data to suggest that such harm would be probable).

8.5.11 #11: Glenn Jones	
Occupation:	Managing Director
Organisation:	Biolytic Systems Ltd
Date of Interview:	17/June/1996

The following account was produced following a meeting with Mr Glenn Jones of Biolytic Systems Ltd at their offices in Washington, Tyne and Wear, United Kingdom.

The major barrier to the development of treatment techniques is the that of cost. Mr Jones identified a simple equation between £30/ton for in or ex-situ remediation and £17/ton for encapsulation. However, he argued that even if remedial techniques become cheaper there is still the problem of perception. He considers developers to be apprehensive of complex approaches to contaminated land problems. Mr Jones identified a feeling amongst developers that remedial techniques cannot be relied upon to deliver precise results. In addition, he contends remedial techniques are commonly considered superfluous and are often the first element of a development to be cut when cost reductions are sought.

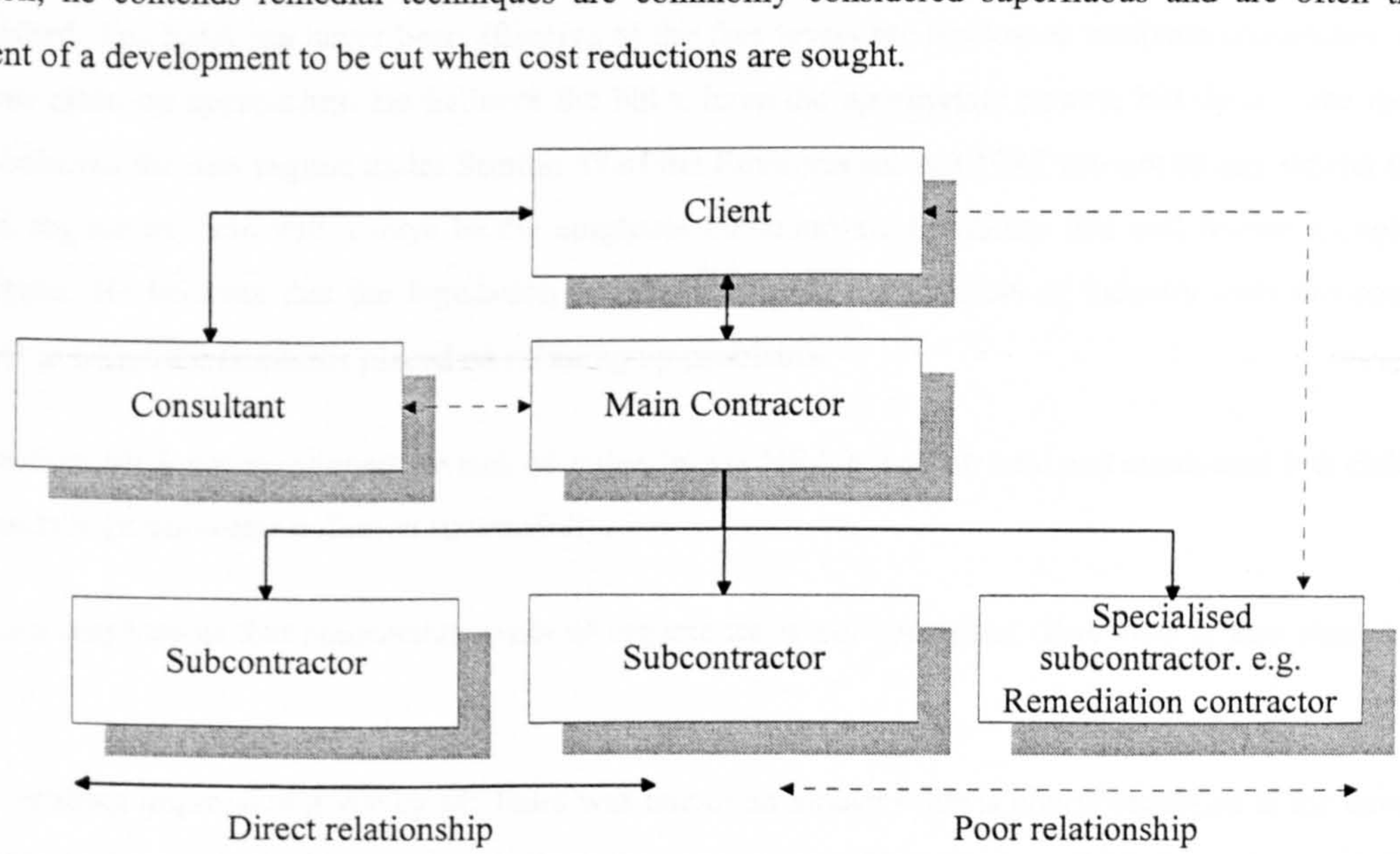

Figure 1: Consultant, Client, Contractor Relationship.

Figure 1 illustrates Mr Jones' perception of the consultant, client, contractor relationship. He stated that specialist subcontractors have difficulties because main contractors often do not understand the nature of their

work. This problem is exacerbated due to a lack of communication between contractors and the client or consultant. Ordinarily this is not a problem as subcontractors can be relatively unskilled, e.g. being involved in earth movement. However, specialist subcontractors providing remediation services may have particular needs that main contractors do not understand and cannot manage effectively. Mr Jones suggests that specialist subcontractors should ideally act as consultants and have formalised links with consultants or clients. e.g. limited space and cold weather both adversely effect Biolytic's remedial process. However, they have had to work in both situations when their needs were not well understood by contractors. In addition there are no formal ways a subcontractor can make his views known to the consultant in charge of an operation.

Mr Jones stated he had been considering developing a central processing facility to cope with contaminated soil in a style similar to that used in Germany and the Netherlands. However, the recent decision on the Landfill Tax has made this idea uneconomic.

He considers the sources of funding available to be too difficult to be of use to him. Mr Jones stated that the lead times of many sources of research and development funding are in the order of two years and that the uncertainty involved means he cannot afford the time to apply. This is a problem with small enterprise.

The Environment Agency will begin to have an effect in about two years when they finally become established. The NRA has never been effective as the fine levels are too low to motivate companies to adopt rigorous clean-up approaches. He believes the NRA have the appropriate powers but do not use them. Mr Jones believes the new regime under Section 57 of the Environment Act 1995 will not be any stricter than the current regime as there will always be the emphasis on economic feasibility that will favour encapsulation techniques. He believes that the legislation is biased towards the interests of industry over environmental protection with little emphasis placed on cleaning up problems.

(Reflective: Mr Jones mentioned the lack of action by the NRA but as Mr McLeod mentioned it is difficult to demonstrate groundwater pollution successfully.

Mr Jones emphasises that consultants depth of experience is not consistent. This view is also shared by Mr Dyer.

The overriding impression given by Mr Jones was one of an industry that is poorly regulated to the extent that operators deliberately take liberties in an attempt to save money. The extent to which this is true is debatable. He emphasised that weak regulation, deregulation, and the need to minimise costs means that the potential to develop new techniques is poor.)

8.5.12 #12: Brian Lassman

Occupation:	Director
Organisation:	ECO-Environmental Services (United Kingdom) Ltd
Date of Interview:	4/July/1996

This account is based upon notes taken during an interview with Mr Brian Lassman. It was conducted at the Biotechnology Means Business Roadshow at Coombe Abbey in Warwickshire, United Kingdom.

Eco-Environmental Services (United Kingdom) Ltd constituent companies include ECO-Composting Ltd, Patterson Exploration Ltd and McKim and Creed. PXS developed the bioremediation technique over the past 8 years in the United States.

Mr Lassman, however, is a relative newcomer to the remedial treatment field. Whilst exploring innovative uses for compost he contacted the Ministry of Defence with the suggestion that he could remediate hydrocarbon contaminated soil using a bioremediation technique that uses compost in the process. The MoD accepted and he contacted PXS in the United States for advice. The MoD was used as a demonstration project for the technique. Mr Lassman recognises the importance of providing a track record.

The demonstration project was carried out in September 1995. Mr Lassman contents this was vital in his effort to secure more work for the company. Three projects have now been carried out for major companies. However, these companies wish the work to remain confidential. Mr Lassman is not allowed to use any of the data collected for research purposes in promotional material.

The recent decision on the Landfill Tax does not seem to have affected Mr Lassman's view of the industry. He contends that he can compete with landfill on a cost basis. He can clean petroleum contaminated soil at approximately £15/ton

8.5.13 #13: Linda Fiedler

Occupation:	Work Assignment Manager
Organisation:	USEPA Technology Innovations Office
Date of Interview:	17/September/1996

The following account was produced after a meeting Linda Fiedler in the Offices of the Technology Innovations Office (TIO) in Washington D.C., United States.

Ms Fiedler began by describing the role of the TIO as informative. She stated they provide data and guidance to parties such as: the United States Department of Energy; the Department of Defence; or Responsible Parties (RPs) that have been identified in Superfund Cleanups. RPs are responsible for the clean-up of approximately 75% of Superfund sites. However, Ms Fiedler did state it is difficult to secure funds from private firms to help develop remedial techniques.

(Reflective: The role of the TIO is similar to JUMU in that they disseminate information and attempt to stimulate leads for industry. However, TIO is solely involved with the promotion of innovation in the United States while the role of JEMU is international)

The TIO is involved with both RCRA and Superfund programmes as innovative solutions are required to clean-up both old contamination and prevent new pollution from occurring.

When discussing the dynamic system illustrated in Figure 5.1 Ms Fiedler made the point that it will not function smoothly as the demand for remedial techniques is not constant within the United States.

Ms Fiedler stated that public opinion effects the development of innovative remedial techniques in two ways: in relation to the making of policy and the development of innovative remedial techniques; and in terms of the reaction to the technologies developed. e.g., in the latter case, *ex-situ* techniques have a bad reputation in the United States as the public fear the release of hazardous substances to the atmosphere during remediation. This limits the potential of such techniques.

Ms Fiedler perceives a move away from the *preference for treatment* caveats introduced by SARA in 1986. She described how after the promulgation of SARA the need to develop innovative techniques was considered important and how the SITE programme was established for this purpose. She stated that initially,

treatment systems were evaluated. However, they were found to be expensive and have emission problems. This was followed by a move towards in-situ treatment, a remedial solution that though better on emissions is still quite expensive. She considers the new area of development to be natural attenuation, monitoring and active containment.

Ms Fiedler holds the opinion that the levels of protection required in the United States are unrealistic in their risk assumptions. She stated that this realisation has taken time to develop but that this view is becoming popularised in studies by organisations such as the GAO. These studies illustrate the inefficiencies involved with Superfund and put the case for a move towards a *suitable for use* approach. Actions such as the Brownfield Action Agenda and NTC operations are an illustration of an attempt to solve problems pragmatically. However, Ms Fiedler considers it unlikely that these policy changes will go as far as the introduction of a *suitable for use* style of approach in the United States. She contends that these moves are- in addition to an attempt to cut costs- an attempt to alleviate the threat of liability involved with sites that may not be excessively dirty but may remain vacant because of developers' fear of Draconian measures under Superfund. In addition, they are a reaction to the high costs of Superfund RIs that are considered overly prescriptive by industry. She considers that the trend towards brownfield development and NTC operations may encourage the use of remedial techniques but not necessarily high technology solutions.

Superfund is risk driven and depends on an interpretation of how clean is clean.

Ms Fiedler considers companies such as ICI and Dow Chemicals to be the principle market for remedial techniques. Consequently, the opinion of industry carries some weight particularly because of the election of a Republican Congress. She stated that congress attempts to alter policy as the law cannot be altered without inflaming public opinion.

8.5.14 #14: John Martin

Occupation:	Chief, Contamination and Remediation Branch
Organisation:	USEPA
Date of Interview:	19/September/1996

The following account was produced after a meeting with John Martin of the USEPA at the National Risk Management Research Laboratory in Cincinnati, United States.

Mr Martin described how the SITE programme provides funding for the development of emerging technology and the verification of developing technology. However, he pointed out that there have been problems with the USEPA budget and at the time of the interview the reauthorisation of the budget was 9 months late. Mr Martin predicted that when the new budget is agreed the funding for the development of emerging technology will be cut leaving only the verification role for the SITE programme. He stated that this illustrates the slightly uncertain future of the USEPA and how congress was in the process of reauthorising the legislation that gives the USEPA its mandate. He also predicted that SARA would not be reauthorised. He believes that the legislation that is to replace SARA will place less of an emphasis on the *preference for treatment* requirements found in SARA and shall attempt to reduce the potential for litigation. Mr Martin perceives a move to place less emphasis on the requirement that all sites be vigorously cleaned.

Mr Martin contends that the uncertainty surrounding the reauthorisation of Superfund is damaging to the development of treatment techniques. He considers it most important that some form of legislation be authorised as the present situation causes uncertainty.

Increasingly, the SITE programme involves the verification of containment or natural attenuation. When asked how the public will react to a less stringent approach to the remedial treatment of contamination he stated that in cases where there is a local community involved it will be difficult to move to more relaxed standards. However, he thinks it will be more straightforward in areas that are isolated.

Mr Martin stated that United States policy has requirements that the Best Demonstrable Available Technique and Best Available Treatment be used. However, regulators have been slow in introducing these economic factors into the requirements that environmental targets be achieved. Mr Martin stated that cost effectiveness is one of the reasons the SITE programme was started and now that the development of innovation is to be curtailed its main role will be to verify technology and analyses cost.

Mr Martin believes the reason for the present prevarication concerning Superfund reauthorisation is primarily due to it being a groundwater protection programme and because land contamination requires different solutions.

8.5.15 #15: Michelle Simon

Occupation:	Site Manager
Organisation:	USEPA, Site Management Support Branch
Date of Interview:	19/September/1996

The following account was produced after a meeting with Michelle Smith of the USEPA Site Management Support Branch at the National Risk Management Research Laboratory in Cincinnati, United States.

The Site Management Support Branch (SMSB) are responsible for site management at SITE sites. They provide technical support, help design remedial projects and they review the effectiveness of remedial techniques. Mrs Simon is responsible for projects relating to soil vapour extraction (SVE) and bioventing.

Mrs Simon stated that it can be difficult to persuade RPs to co-operate in SITE demonstrations as their primary goal is to clean-up land as quickly and efficiently as possible.

She stated that SVE and bioventing are used when natural attenuation is not feasible. These techniques are increasingly in demand as they are in-situ and less complicated that many ex-situ processes. In addition they are low energy and are effective when used against non-chlorinated organic compounds. They can be used on chlorinated compounds such as TCE but less effectively due to their more persistent nature. In order of preference natural attenuation will be used first then bioventing followed by SVE.

SVE and bioventing have been able to meet the tough Superfund clean-up standards in some cases but ultimately it is difficult to achieve these standards. However, as requirements for clean-up are relaxing then these techniques are looking more useful.

SVE is used in 19% of Superfund cleanups.

Mrs Simon believes the biggest drawback of SVE and bioventing is the uncertainty surrounding their use. There is a need for more basic understanding of the way techniques interact with contaminants and the environment. Lack of knowledge of these things gave such techniques a bad reputation when they were first developed.

Mrs Simon believes the remedial technique most commonly used in the future will be natural attenuation, the destructive technique of choice will be bioremediation and low energy techniques will be preferred over high energy techniques.

8.5.16 #16: Edwin Barth	
Organisation:	USEPA, Residuals Management Branch
Date of Interview:	19/September/1996

The following account was produced after a meeting with Mr Ed Barth of the Residuals Management Branch of the USEPA at the National Risk Management Research Laboratory in Cincinnati, United States.

Mr Barth stated that the Brownfields Action Agenda was introduced because Superfund was considered too rigid. He believes that high technology solutions will be used less and mostly on the higher risk sites such as DOE and DOD sites where complex cocktails of chemicals and nerve agents will require special treatment.

As an example of the more pragmatic mood Mr Barth stated that RCRA is moving towards Risk Based Corrective Action (RBCA) that recognises that natural attenuation is a valid option. He also believes that Superfund NP sites will increasingly be contained and remediated by natural attenuation.

He contends that the Brownfield Action Agenda will succeed where Superfund failed as the public will be more willing to accept the low key treatments it will involve. He cited an example in Virginia where Mercury contamination was to be remediated by an ex-situ process but the local residents decided they would rather have it contained than suffer three years of treatment and the possibility of air pollution. He believes the public place a higher priority on the risks associated with air as opposed to water or ground pollution. He also maintains that property values play an important role in the decision making process of the public.

Mr Barth stated that when Superfund is reauthorised it will no longer contain the *preference for treatment*. He considers this to be due to the influence of the Republican congress who are sympathetic to the view that industry has been forced to pay too much for inefficient Superfund clean-ups. He suggested that the new legislation will have a technical and practicability waver that allows difficult sites to be contained on the grounds that remediation is not feasible.

He does not think there will be a large pubic outcry against these measures as he believes the public are becoming aware that the Superfund programme has been ineffective.

8.5.17 #17: Round Table Discussion With: Dr Jim Ryan, Dr Taras Bryndzia, Dr Wendy Davis-Hoover and Dr Dave Carson. .	
Organisation:	USEPA Land Remediation and Pollution Control Division
Date of Interview:	19/September/1996

The following account was produced after a round table meeting with Dr Jim Ryan, Dr Taras Bryndzia, Dr Wendy Davis-Hoover and Dr Dave Carson of the USEPA Land Remediation and Pollution Control Division at the Centre Hill Research Laboratory in Cincinnati, United States.

Three routes were identified for the development of new remedial techniques. These were:

- Scientists who see the potential for novel technical applications of technology. These cases make up approximately 50% of the SITE programme but these developers commonly run out of money as receiving pay back on a new technology takes time.

- Businessmen who see the potential value of technology crossovers. e.g. a technique to remove herbicide from potatoes in the food manufacturing process was developed to remove TNT.

- Companies threatened with environmental liability can develop solutions to their own problems and then develop them commercially. However, such companies may not be willing to share their experience. e.g. Monsanto hold the patents for two remedial techniques although this fact is not made public for fear of adverse publicity. (Reflective: see also the experience of Brian Lassmann)

It was agreed that all these developers face the same barrier when attempting to develop remedial techniques on a large scale. A possible solution to this is to license out the right to apply techniques rather than develop the technique further. However, this still does not solve the problem of a lack of commercial experience.

It was agreed that all of these routes to the development of new techniques are stimulated by policy but that mistakes were inevitable and this is why it has taken until now for more pragmatic policies to be developed. It was discussed how policy is driven by public perception of risk which in turn drives the type of research that is carried out. This results in laws that are a problem as the law is reactive and poorly defined. Superfund underestimated the scale of the problem, an error that was compounded by the fact that no evaluation occurred until public perception was so strong that the legislation was revisited. Consequently, the Superfund

programme is reactive and the standards are ultimately driven by technological capability. (Reflective: The problem is that the method of arriving at these conclusions are convoluted)

It was suggested that the price of real estate in some cases means that new techniques are becoming cost effective. This is the case in areas such as California and parts of the east coast. However, the point was made that the liability regime is still a limiting factor in environmental matters and that policy makers were short-sighted not to expect the levels of litigation created. (Reflective: was too much faith placed in the ability of advanced technology to solve the problems of contaminated land)

The USEPA has a problem with public perception, i.e. the levels of clean-up that are chosen are not consistent. This is reflected in situations where the more vocal the support for a clean-up the lower the levels required at a site.

The Research Technology Developers Forum was discussed as an example of an initiative to encourage co-operation between the USEPA and chemical companies. This is an unusual move in the United States where this relationship is quite adversarial. The initiative has experienced problems companies are loathed to co-operate with the technical side of the USEPA for fear that the regulatory side will prosecute them.

8.5.18 #18: Ed Bates

Occupation:	Site Manager
Organisation:	Unites States Environmental Protection Agency
Date of Interview:	20/September/1996

The following account was produced after a meeting with Ed Bates of the USEPA Site Management Support Branch at the National Risk Management Research Laboratory in Cincinnati, United States.

Mr Bates stated that the developers of treatment techniques are commonly small companies. Consequently, they find it difficult to develop a technique to full field scale and even harder on the commercial scale. Firms such as this do not recognise the difficulties they will face when attempting to develop treatment techniques. They assume good ideas will find buyers immediately.

He believes the public sector has developed some interesting technology because it is not hampered by the problems of developing techniques at field and commercial scale. Wetlands (reedbeds) and BCD techniques were developed in the public sector. The problems of publicly funded projects are that cost can be excessive there may not be a markets for the techniques.

Mr Bates believes that when private organisations are dealing with their own problems they are less likely to incur environmental liabilities. Therefore, companies are more willing to risk advanced techniques where the regulators are not involved. The problem is that the information gathered by private organisations is not in the public domain. This means that the profile of such techniques is not enhanced and often the developers of the techniques used are prevented from using data collected from the work done to publicise their techniques. (Reflective: this is the problem faced by Brian Lassmann)

He believes the influence of public opinion can be damaging for innovative techniques. The public opinion of incineration illustrates this point well as although the technique can be used successfully to destroy contamination in soils the public opinion of the risks involved means its use is limited.

Mr Bates feels that public interest and industrial lobby groups balance each others effect. Some sides will gain an advantage temporarily but the overall effect is one of balance. He cited Reagan's failed attempt to remove the burden of environmental regulation as an example.

Mr Bates considers the different regulatory philosophies of RCRA and CERCLA to be the result of their creation by separate congressional acts. Superfund is risk based while RCRA deals with waste streams. The result is that regulation can be inconsistent. Superfund sites can create waste that is the responsibility of RCRA regulations. This creates difficulties for the developers of new remedial techniques. e.g. contamination treated by an ex-situ process is covered by RCRA but not if it is treated in-situ. This means that the developers of new remedial techniques face uncertainty. These problems are overcome in the trial stages of development by the Superfund Treatability Exemption but not when full scale field tests are required.

Mr Bates explained how public opinion influences policy in phases. He believes that the various environmental agencies have their mandates altered at varying rates. He proposed this as the reason why CERCLA and RCRA do not always appear to work in harmony.

8.5.19 #19: Kandi Brown	
Occupation:	Environmental Technology Developer
Organisation:	IT Corporation
Date of Interview:	20/September/1996

The following account was produced after a telephone conference with Kandi Brown of IT Corporation in California and Brunilda Davila of the USEPA in Cincinnati.

Mrs Brown stated that without the SITE scheme it would be very difficult to develop treatment techniques. The SITE programme allows data to be collected about a technique and this makes potential users more comfortable about using a technique. The SITE scheme is a good stepping stone to full scale development.

As a large company IT are at an advantage as they can afford to test techniques in the field. Clients do not like to be the first to have used a novel technique. For this reason small companies often come to IT to request help in developing techniques.

She believes that passive, in-situ and those techniques that depend to a large extent on monitoring are becoming popular. These techniques have been developed in the last three years on the west coast at military bases. This move from high to low tech solutions was not foreseen in the 1980s but the techniques are the most cost effective.

Mrs Brown stated that the public are becoming increasingly knowledgeable about contaminated land issues. She stated that although IT attempt to educate both the public and regulators when using remedial techniques it is inevitably that the more high profile the site the more education and assurances have to be given.

Increasingly clients want to be seen to be environmentally aware. This is a direct result of strong regulation. This means that SITE schemes can be arranged but it can be a burden on regulators and clients and it can takes some encouragement to get SITE schemes approved. In addition, she stated that clients may be apprehensive as they commonly wish to retain confidentiality. Federal regulators can allow for confidentiality but state regulators may not.

When asked about the difficulties of the regulator/client/contractor relationship she stated that it was important to involve regulators from an early stage in a project as this can mean a reduction in project time

and cost. (see article in EST on regulators doing this?). She emphasised that communication is vital in any project. (Reflective: the large size of IT, their experience and use of managerial skills demonstrates the maturity of the United States market)

8.5.20 #20: Neil Davies	
Occupation:	Senior Project Engineer
Organisation:	Geosyntec Consultants
Date of Interview:	23/September/1996

The following account was produced after a meeting with Neil Davies of Geosyntec Consultants in their offices in Atlanta Georgia, United States.

Mr Davies stated that RCRA applies to current sites in a similar manner to IPC in the United Kingdom-Superfund applying to closed sites that are contaminated. He stated, however, that at Superfund sites RCRA may be quoted as an Applicable Relevant and Appropriate Requirement as may other state or city regulations. He described how the USEPA manager will decide which regulations are required and that usually this will be the most stringent, although a waver may be granted on certain regulations.

He stated that this situation illustrates the lack of clarity that may exist around a Superfund project, e.g. soils and fluids from boreholes on Superfund sites are waste under RCRA. However, such wastes are increasingly granted a waver. This illustrates regulators are taking a more reasonable attitude. (Reflective: this is true of small points like this but also as Kandi Brown says the early involvement of regulators breeds trust and projects speed up. Find the fast track cleanup reference.) He believes this change in attitude is further illustrated by the way cost is incorporated into the Superfund process. Mr Davies described how Superfund sites are assessed on nine criteria and that initially, cost came quite low on this list but now it is used to delineate between potential techniques. However, he made the point that the protection of the environment, or the "threshold criterion", is still a more important criteria than cost on Superfund sites.

Mr Davies used the example of a site in Louisville Kentucky to illustrate a number of points. The site near a landfill was contaminated by illegally dumped waste. Tenders were invited to remediate the site and eight were received. The more advanced remedial methods tendered were in the order of 80-100% more expensive than incineration and BCD. Mr Davies was initially under the impression that the more treatment techniques would be quoted at cheaper process but he contends that their operators relative lack of experience meant that they were unable to quote prices with any certainty and consequently their tenders were high. He also stated that the site illustrates how the requirement that Superfund sites be extensively cleaned causes problems. He believes it would be more realistic and much cheaper to remediate to 90% and suggests that such clean-ups

would cost only 10% of a normal Superfund site. He believes the site in Louisville illustrates this as while the drums of hazardous material were removed and treated off site it was the final remediation of the contaminated soil that took two years and $20million.

Mr Davies believes that the Superfund programme should take more account of cost effectiveness. Indeed he agrees with PRPs when they consider the Superfund programme to be wasteful. However, he has noticed an attempt by regulators to address this problem. He believes that Non-Time Critical clean-ups and SACM procedures allow regulators and regulated to discuss projects as they develop so removing some of the unnecessary regulatory procedures so reducing the time and cost of remediation. However, he also believes that programmes such as this run by state governments can fall foul of national regulators and their requirements.

Mr Davies believes that it is the protection of groundwater and drinking water that has driven Superfund until now. He made the point that groundwater is considered more important that it is in the United Kingdom and that the American public is more aware of groundwater problems.

8.5.21 #21: Randy Sulivan

Occupation:	Associate, head of operations in Atlanta
Organisation:	Golder Associates (United States)
Date of Interview:	24/September/1996

The following account was produced after a meeting with Randy Sulivan of Golder Associates in their offices in Atlanta Georgia, United States.

Mr Sulivan described the legislative process in the United States in the following way:

1, Congress passes a law;

2, the epa put out regulations; and

3, states introduce realism into the situation and take jobs and common sense into account.

However, he stated that ultimately Superfund remains a federal programme and that this contributes to its rigidity, e.g. federally controlled Superfund clean-ups can require all potential risk scenarios to be covered in an investigation even when the outcome is clear and remedial treatment is proposed voluntarily. He believes this inflexibility has prevented PRPs from volunteering to undergo remedial treatment of their land.

In addition he contends that the problem of contaminated land is commonly exaggerated and that many sites exhibit very low pollution levels.

Mr Sulivan thinks Superfund system is too adversarial and that the risk analysis system on which it is based is too restrictive.

However, he perceives a change in the regulatory environment, e.g. in situations where clean-ups are voluntary then elements of the Superfund process considered superfluous can be foregone. Also, brownfield development is becoming more popular, particularly in the north-east, where the USEPA has been keen to promote the idea that most contaminated sites will fall into the less regulated brownfield category rather than Superfund. This approach coincides with the increased popularity of voluntary clean-up for economic reasons. He believes the PRPs accept that they must remediate their contaminated sites but there is also an increasing need to recycle derelict land.

He suggested this change in attitude may be due in part to the potential cost of cleaning up DOE and DOD sites. Congress has realised that it would be prohibitively expensive to remediate these site to the old Superfund standards.

Mr Sulivan stated that a few companies opt to clean-up their land voluntarily and do so internally. He said that this would involve some of the more high profile polluters such as chemical companies because of a fear of liability and image. However, the majority of the contaminated land work is driven by regulation. He maintains the current stalling of the Superfund programme is having an adverse effect on the market for remediation.

He believes that realistic policies would alleviate much of the need for litigation.

(Reflective: does this mean that industry will only acquiesce when it is their best interest? It appears that friction is initially the result but as regulation develops a consensus if found where industry can see benefits, i.e. the redevelopment of derelict land.)

Mr Sulivan has doubts that the public will put up with lower remediation standards. He considers the public irrational and stated that the perception of risk is a difficult area. e.g. land values will effect public opinion and public opinion of the risks associated with treatment and encapsulation is not rational. In addition, he considers the differences between short and long term risks to be poorly understood.

Mr Sulivan stated that the RCRA regulations are preferred by clients as they offer more realistic standards but also they address waste streams rather than general levels of risk as with Superfund. In addition, he considers the state regulation of RCRA to be less confrontational nature. He suggests this promotes good relationships between regulators and regulated. Mr Sulivan considers this a good situation and not one that favours polluters as there are provisions for reporting pollution incidents and the system is transparent enough to let environmental groups monitor proceedings. (Reflective: in the United Kingdom there has been criticism of a lack of transparency despite laws to enable this. Ends)

Mr Sulivan described how the market for environmental consultancy in the states has matured. He believes that where the United Kingdom consultancy market is approaching maturity in the States it has done so with larger firms left to dominate the market. He pointed out that consulting firms are now going public to fund further acquisitions. M.con and Dames and Moore are both examples.

Mr Sulivan believes that there is a healthy market for treatment techniques in the States but it has reached its zenith and it is now falling off slightly. The work available is for RCRA, Superfund and brownfield development.

The client/consultant/contractor relationship is difficult. General contractors and clients often do not understand the complex earthworks involved with remedial techniques. Increasingly this understanding is growing.

Mr Sulivan stated that the vendors of remedial techniques are unable to offer fixed prices for their techniques and this puts off potential clients.

8.5.22 #22: Dr Stephan Jefferis

Occupation:	Associate
Organisation:	Golder Associated (United Kingdom)
Date of Interview:	12/November/1996

The following account was produced after a meeting with Dr Stephan Jefferis of Golder Associates in their offices in Maidenhead, United Kingdom.

Dr Jefferis believes Section 57 of the Environment Act 1995 introduces a vast legislative framework to control a relatively small problem. The reason for this may be to draw the teeth of the common law and produce a civil law framework with statutory controls. However, common law will remain an important aspect of the regulation of environmental pollution in the United Kingdom because the statutory liability regime in the United Kingdom is primarily geared towards the prevention of serious threats to health. Consequently, the common law will be the only form of redress for smaller incidents of contamination not protected under this system (Reflective: this carries with it the problems associated with common law remedies such as their reactive nature and the requirement of an interest in property). He made the point that air pollution arising from contaminated land may have to be dealt with by the common law under nuisance as there are no provisions to prevent this under statue law. In addition, he stated that ecosystems other than SSSIs are afforded even less protection as only property is afforded protection under the common law.

Draft guidance (DoE 1996) identifies what can be considered a significant risk to human health or the environment and how contaminated land is to be defined. It is clear that contaminated land under the 1995 Act is relatively narrowly defined. Dr Jefferis believes the regulation is an attempt to made it easy for developers to reuse derelict land.

Dr Jefferis made the point that clients tend to accept cheaper quotes for remedial work. However, this as a false economy as firstly, the price of remedial treatment is commonly higher than expected as more contamination is often discovered- i.e. the idea of concentration and quantity- and secondly, the contractors who give cheaper quotes may not be able to achieve their desired results and this may mean an alternative solution is required at additional expense.

The three environmental media are regulated for different reasons. Air for the reason of risk, Water because it is a resource and land is ignored as it is neither a risk or a resource. (reflective: however, when it threatens a

resource it is a risk and it is threatening both greenfield sites and groundwater) Air pathways usually dominate the mobility of contaminants.

A problem faced by new techniques such as active containment is that regulators need to decide what aspect of the system to regulate. At the present concentration is the driver for remedial treatment but quantity defines contamination. However, he believes the regulation of active containment will probably be to drinking water standards because this is how water is regulated, i.e. as a resource.

Compliance costs of the Landfill Tax will actually be more than the tax level due to administrative costs. He suggested a cost of £14-21 for a tax level of £7.

Dr Jefferis believes treatment techniques have the ability to generate their own markets. i.e. as the remedial treatment of many sites is not currently feasible they remain encapsulated. However, as new techniques emerge that may be able to deal with these problems cost effectively then the clean-up complex contaminated sites may be feasible. In effect the new techniques can become the BPM where there was not a solution before.

If a new technique is developed in the construction industry it will soon be recognised and copied. Patents are not that effective and consequently not always sought.

8.5.23 #23: Malcolm Lowe	
Occupation:	Head of the DoE Contaminated Land and Liabilities Division (CLLD)
Organisation:	DoE
Date of Seminar:	20 & 26/November/96

This account is based upon two seminars: a one day seminar on interpreting the Draft Guidance on Contaminated Land organised by the University of Cambridge Programme for Industry in Cambridge, United Kingdom; and a meeting of the EIC Contaminated Land Working Group at the offices of Bristow, Cooke and Carpmael, London, United Kingdom.

Mr Lowe stated that a decision was made to avoid complex technical issues in the guidance. The draft statutory guidance is deliberately vague because different local authorities with different problems will have to implement it. It provides a pointer towards other forms of information.

Mr Lowe stated that there was a dramatic reaction to the proposed introduction of the Section 143 Registers as at the time contaminated land liabilities were poorly understood. (Reflective: this was also the opinion of Gavin Costigan, that the legislation was not understood until its final stages in parliament). This mistake made clarification an imperative for any future legislation- hence the large amount of consultation that has been undertaken on the Section 57 of the Environment Act 1995.

The intention of the new regime is to:

1. improve the clarity of the existing regime in terms of the range of controls (this is the role of the statutory guidance and the EA);

2. to clarify ambiguous definitions (such as the definition of harm in the present regulations on statutory nuisance); and

3. to reinforce the concept of *suitable for use.*

Mr Lowe stated that *suitable for use* deals with contaminated land by assessing it in terms of actual risk, including the wider environment in a cost effective manner. In Europe this "British approach" to contaminated land is finding favour with policy makers. The regime focuses on realism, i.e. what can be

achieved. "Hard policy choices" had to be made because there is not enough money or knowledge to deal with the problem of contaminated land immediately. Contaminated land is defined in relation to current land use and problems are addressed when land use changes. He stated that the majority of derelict and contaminated land will be cleaned up through the process of redevelopment and that PPG23 is being amended to accommodate the new regulations. The policy tools it employs are:

- redevelopment;
- planning and building controls;
- public investment and development corporations;
- and direct regulation.

However, when asked how local authorities would deal with the flood of newly recognised contaminated sites that the regulations will bring. (he accepted this would happen), Mr Lowe adopted the contradictory position that there are no real changes in duty from that of statutory nuisance and that the Guidance and the Act are an attempt to re-affirm the statutory duties already in place. Consequently, it should not be a big event as there is no new burden. However, members of the EIC made the points that: contaminated land has not been considered in this manner before; the guidance introduces a strategic approach to the problem of contaminated land; and it is not reasonable that no additional money will be made available to run the scheme. (Reflective: just because there are no new duties this does not mean that the duties were upheld in the past. How many contaminated land sites have been remediated because they were creating a nuisance).

The deregulatory approach means that to a certain extent cleanup will be voluntary. It is a system designed to avoid litigation, i.e. enforcement is at a long chain of action that ends with criminal measures. This is in recognition of the problems that will be caused if regulators have to go to court to resolve problems.

Guidance on risk assessment is to be produced but Mr Lowe emphasised that consultants would have the freedom to assess risk in whatever manner they choose provided they can justify their actions. The ICRCL guidelines are to be replaced by the CLEA guidance.

8.5.24 #24: Professor Malcolm Grant	
Occupation:	Professor of Land Economy
Organisation:	University of Cambridge
Date of Seminar:	26/November/1996

This account is based upon a seminar on interpreting the Draft Guidance on Contaminated Land organised by the University of Cambridge Programme for Industry in Cambridge, United Kingdom.

Professor Grant emphasised the DoE's paradoxical position when it states that the new contaminated land provisions can firstly, introduce a system for the regulation and remedial treatment of contaminated land, and secondly, be easily and cheaply introduced due to the fact that the provisions contain no new statutory duties.

Professor Grant stated that the difference between CERCLA and Section 57 of the Environmental Act 1995 is that the latter does not involve joint and several liability. However, it is strict, retrospective and includes a wide range of potential polluters. This wide range of liability is narrowed down on a sequential and chronological basis with the most recent offenders being liable. He argued that the exclusion provisions do introduce a form of joint and several liability as where a site involves an orphan share of liability, for which there is no money to pay, then local authorities will attempt apportion this liability on the Appropriate People (AP) identified under the Act. He considers these AP the equivalent of Superfund's Responsible Parties (RPs) and consequently, in sites where there are orphan shares of liability remediation, he believes remediation orders may lead to litigation as to the exact apportionment.

Land use planning plays an important role in the *suitable for use* approach. Planners and local authorities have dual powers to develop strategic plans under PPG2 and PPG23. However, there is a funding gap between the redevelopment process and the orphan sites. Professor Grant suggests using the process of planning gain to bridge this gap and solve the problems of brownfield development. i.e. to encourage the market for remediation by underpinning it with the planning process.

8.5.25 #25: Stephen Tromans	
Occupation:	Head of Environmental Law Division
Organisation:	Simmons and Simmons

Questionnaire Response

1. Question. Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

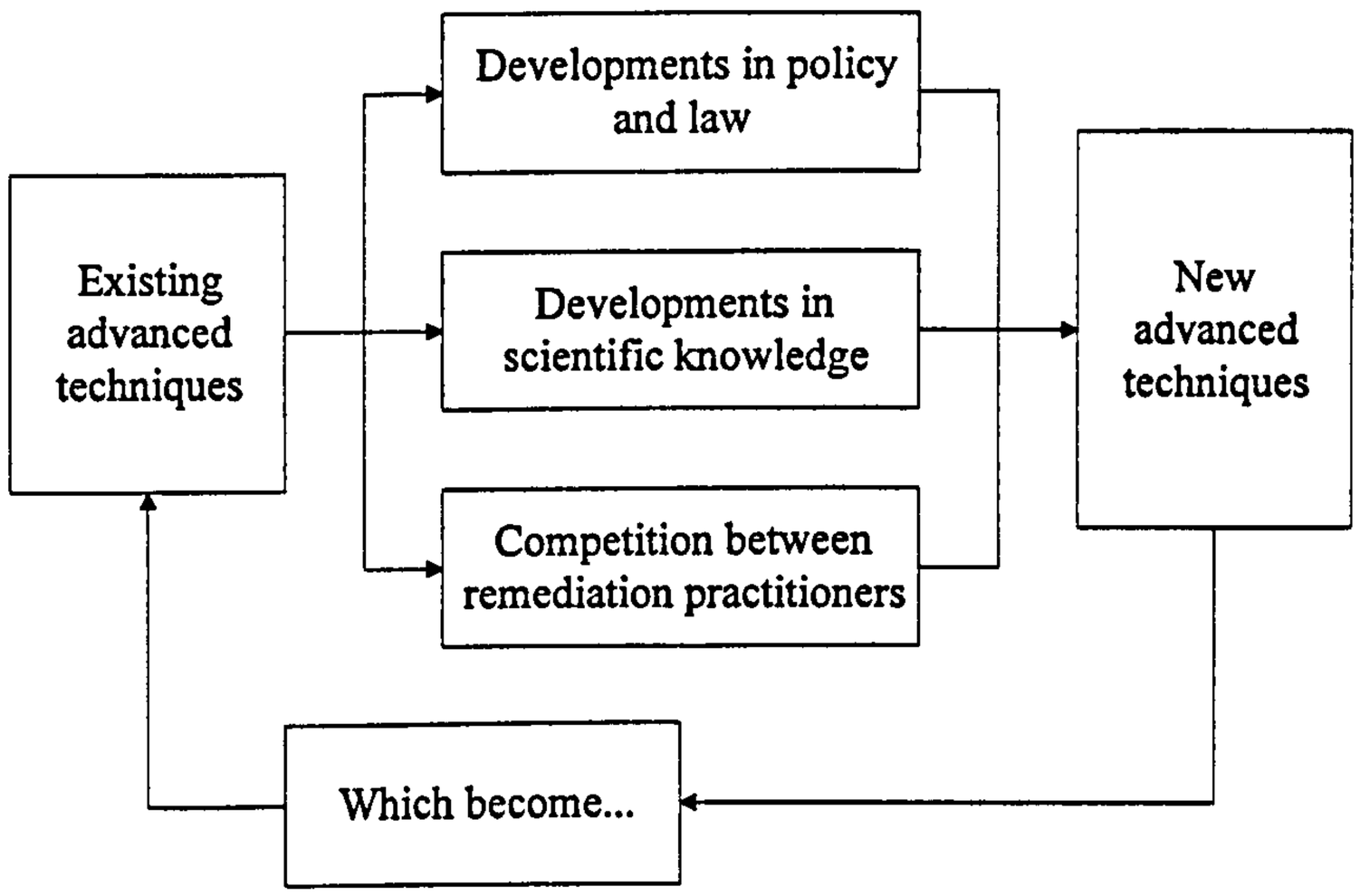

Figure 1: Troman's Model of the Influences on the Development of Treatment techniques

The model illustrated in Figure 1 attempts to suggest that something is needed to "push" the development of new techniques. Any of the three factors indicated could, in the absence of the others, provide that impetus.

The two figures in the questionnaire were to me unhelpful because the items placed "at the centre" were not shown to be causally linked with the other factors, and therefore appeared both more and less important than them.

2. Question. In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques?

Uncertainty as to the law and its enforcement are those with which I am most familiar. My impression is that uncertainty as to whether a particular level of remediation is required by law, and if so whether it will be enforced and the level of penalty for non-compliance, discourage land owners from investing in remediation to that level. This encourages reliance on existing remedial methods by environmental consultants in an attempt to make cost attractive in a situation where liabilities may never materialise or may be low if they do.

4. Question. How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

By launching them first in a jurisdiction where policy and law is most favourable to their use, or by cutting prices initially in order to attract and carry out enough contracts to have a credible track record.

5. Question. Does the state owe any responsibility to the developers of treatment techniques?

No - but it owes a duty to the public to ensure adequate protection of the environment, which I would say includes, in a market system, removing the externalities referred to in the question.

6. Question. In what direction is contaminated land policy moving?

Very much towards risk assessment. At this stage it is impossible to say what the standard of acceptable risk (the other side of the "significant harm" coin) will be. Also, towards ensuring so far as possible that remediation occurs as a pre-condition to development. when there is a private pocket to fund it.

8.5.26 #26: Jim Begley	
Occupation:	**Principal Consultant**
Organisation:	**AEA Technology**

Questionnaire Response

1. Question. Do you agree with either of these representations of the process of innovation or can you suggest an alternative model?

Figure 1 with the addition of the profit motive of the entrepreneur. Comparing the market for innovative methods between the United States and United Kingdom indicated tighter regulation driven innovation. A key aspect is the cost and availability of low-tech options like landfill. If low cost landfill is unavailable then a more innovative technical option is cost effective.

2. Question. In what area, and how, have you seen uncertainty hinder the development of innovative remedial techniques?

Uncertainty is based on undemonstrated:

- cost;
- effectiveness (ability to reach clean end point);
- implementability;
- side effects;
- residual risk;
- no one in private enterprise wants to be first.

3. Question. In what area, and how, have you seen uncertainty or confusion resolved for the benefit of the development of treatment techniques?

Private/public partnerships are the best vehicle to resolve uncertainty. In the United States public facilities, i.e. military bases, have been used as testing grounds. The problem holder is big enough to absorb a failure without risk and see a potential cost saving benefit worth the risk.

4. Question. How can operators of innovative remedial techniques gain the experience and credibility that is so vital for their acceptance?

Without the benefit of a public demonstration site (see above) it would be best to "start small", develop a track record and publicise the results. In my work I am assisting technology developers with laboratory scale work and moving technologies to field demonstrations by developing relationships with problem holders.

5. Question. Does the state owe any responsibility to the developers of treatment techniques?

The state should provide adequate regulation to protect public health and the environment for all. Beyond that the state can improve the environment and improve the economy, trade balance etc. by providing public/private support to developers.

6. Question. In what direction is contaminated land policy moving?

slowly forward in the United Kingdom.

leveled out in the United States

7. Question. How will the global market for treatment techniques develop in the future?

Global markets will differ regionally. There is a bigger market for basic technology, i.e. carbon treatment for water and air, than for more innovative methods. As developing countries move from clean water, to clean air and finally to contaminated land issues innovative technology markets will grow.

8. Question. What types of remedial techniques will be successful...

...and what characteristics will they have?

those with:

- competitive price;
- assured end points;
- best timelines to completion.

They shall have:

- low levels of uncertainty;
- fit within a package of kit and/or service; and
- strong regulatory support, i.e. destroy contaminants or bind it permanently with minimal associated risks.

9. Question. What are the most pressing threats and opportunities facing the vendors and developers of innovative techniques for the remedial treatment of contaminated land?

The right timing is the best opportunity and the biggest threat, having a product that fits the market need is the key.

8.6 APPENDIX 6: CIVIL ENGINEERING AND PROCESS BASED FOR REMEDIAL TREATMENT

8.6.1 Civil Engineering Based Methods

These involve the use of conventional civil engineering techniques either to remove the contaminant source, or to modify contaminant pathways without necessarily removing, destroying or modifying the source.

Excavation

Excavation involves the controlled removal of soils, fills, sediments, sludges and construction debris prior to its:

- Off-site disposal to a licensed facility.
- The disposal of the material on-site in a suitably prepared and, if appropriate, licensed facility.
- The treatment of the material either on or off-site at a licensed treatment facility.

Table 26: Potential Advantages and Disadvantages Off-Site Disposal

Potential Advantages: Applicable to a wide range of contaminants Contamination is removed from site Allows for improvement of poor ground conditions Operations can be carried out over relatively short periods Allows the physical access to ground to assess contamination Relatively simple to supervise and monitor
Potential Disadvantages High cost of handling and transporting large volumes of contaminated material Restricted use on sites with operational structures and services Excavations require support Groundwater control may be required and water in excavations will require treatment Vehicle movements can present noise and nuisance to local populations Suitable waste disposal facilities may not be available Fill material may not be available Health and safety implication of handling contaminated material

On-Site Disposal

On-site disposal can be considered when:

- the volume of contaminated material on-site is too great for off-site disposal;
- when such facilities do not exist;

- where the contaminated material is not amenable to other forms of treatment; or

- as a part of a "modified design approach" for a new development where part of the site is reserved for waste disposal purposes in order to free the remainder of a site for development.

However, in law there is a general prohibition of the deposit, treatment, keeping or disposal of controlled waste in, on or under land except in accordance with a waste management licence. Consequently, if on-site disposal is to occur a waste management licence is required with the associated requirements for long-term monitoring and integrity of the disposal area.

Table 27: Potential Advantages and Disadvantages On-Site Disposal
Potential Advantages: Suitable for use on very large sites where off-site treatment or disposal is not feasible Allows for the implementation of a "complete" solution Allows for the controlled disposal of the waste and allows direct supervision
Potential Disadvantages The possible need to obtain and maintain approval to operate a waste disposal facility under waster management and planning legislation The need to undertake engineering works on site to prepare for the disposal of the waste The requirement to following licensing conditions The need to undertake monitoring over the long term Possible long-term restrictions on land use Long term responsibility of site "operator" until WRA accept surrender Possible future liabilities and insurance implications

Cover Systems

Cover systems involve the placement of a specified depth of "clean" cover material over the surface of the contaminated ground, thereby protecting above-ground targets from contact with contaminants. This can also involve the isolation of contaminants beneath hardcover.

In addition to the function of protecting above ground targets, a cover system can also be used to protect building services to prevent ingress of gas, leachate and soil fluid. If the cover layer is deep enough then services can be installed within the cover layer. If this is not the case they can be installed in lined trenches.

Covers can also be used in conjunction with vertical and horizontal barriers to encapsulate a site. As with all engineered solutions, these systems require careful design, high standards of installation and long-term performance testing.

Table 28: Potential Advantages and Disadvantages Cover Systems
Potential Advantages: Applicable to a wide range of contaminants Well established technique Economical even on large sites where other techniques become prohibitively expensive
Potential Disadvantages Long-term durability May be susceptible to long-term degradation by some contaminants Failure to accidental or unauthorised disturbance of cover material Need for long-term monitoring May impose constraints on the use of the site Will not prevent lateral migration of soluble contaminants in groundwater

In-Ground Barriers

In-ground barriers physically isolate contaminants from the surrounding media either on a temporary basis or to block the movement of contaminants over the long-term. Theoretically it is possible to place vertical barriers around the sides of a contaminated area which when keyed into a natural low permeability soil layer and combined with a cover system can isolate the contaminants. Types of vertical barrier include:

Table 29: Types of Vertical Barrier
Displacement systems Sheet steel piling Vibrated beam wall Membrane wall **Excavated Barriers** Secant wall Concrete diaphragm Shallow cut-off walls Slurry trench walls **Injection Barriers** Chemical grouting Jet grouting Jet mixing Auger mixing

The effectiveness and applicability of barrier methods vary according to the types and nature of contaminants present, the physical conditions on site, the design life of the barrier and the methods and materials used. In-ground barriers are a well established technique in civil engineering terms and can provide an economical solution in certain applications, particularly where:

- Substantial volumes of contaminated material are involved
- Alternative treatments are not available

- The public health, environmental risks and costs associated with other methods of treatment are high relative to the gradual failure of a containment system when regular monitoring and supervision are provided.

Table 30: Potential Advantages and Disadvantages of In-ground Barriers
Potential Advantages: Economic where large volumes of contaminated material are present and where removal or treatment are not an option Can be used to control soil, gaseous and liquid hazards Applicable to a wide range of contaminants and soil types Can be used in combination with other remedial methods and as a temporary measure
Potential Disadvantages Lack of information on long-term performance and durability Installation require unrestricted access Barrier material and contaminants may be incompatible Long-term monitoring required Need for groundwater control measures

Hydraulic Measures

Hydraulic measures can be used in the remediation of contaminated land by:

- Managing the local hydrological regime to prevent or reduce contact between a contaminated ground mass and surface or groundwater bodies; and
- Reducing or containing a plume of contaminated groundwater

Such measures can be used in the short-term to contain a plume of contaminated groundwater or in conjunction with other methods such as barriers in the longer term.

Table 31: Potential Advantages and Disadvantages of Hydraulic Measures
Potential Advantages: More economic that physical barriers in some situation High degree of design flexibility and moderate operational flexibility Applicable to most contaminants present in a soluble form Applicable to operational sites provided measures are taken to unsure ground stability Can be integrated with source control measures to offer a more comprehensive treatment
Potential Disadvantages Detailed characterisation of local and regional hydrological regimes is required Possible need for approval to abstract or discharge waters Requires long-term monitoring, maintenance and adjustment May have to be applied over prolonged periods if not permanently System design is highly site-specific and requires specialist input

8.6.2 Process Based Methods

Techniques for the remedial treatment of contaminated land can be loosely grouped into the categories listed in Table 32. This classification is that used by the Warren Springs Laboratory[17].

Table 32: Categories of Remedial Technique (After Crowcroft et al. 1992)

Biological treatment techniques dependent upon the biological transformation or mineralisation of contaminants.
Chemical (including stabilisation techniques) treatment techniques used to destroy, fix or neutralise contaminants.
Physical treatment techniques used to remove contaminants from the soil matrix and concentrate them for further processing or removal.
Solidification treatment techniques used to encapsulate contaminants in monolithic solids of high structural integrity.
Thermal treatment techniques based upon incineration, gasification or pyrolysis at elevated temperatures.

Process based methods may be applied in-situ or ex-situ. Ex-situ refers to the processes applied to excavated soil either on or off-site. In-situ refers to processes occurring in unexcavated soil, which remains relatively undisturbed. In-situ application avoid the cost and potential health, safety and environmental impacts associated with the excavation of contaminated materials. In practice ex-situ techniques tend to be used more widely as they allow greater control over the treatment process. In-situ techniques have a higher degree of uncertainty in relation to: the behaviour of the contaminants; the control of the treatment area; the effect on the surrounding area; and, the demonstration of the effectiveness of the treatment (Martin & Bardos 1996).

Thermal Treatment Techniques

Thermal treatment techniques are most commonly used to remove or destroy toxic organic contaminants by combustion although they can also be used to treat asbestos or volatile heavy metals such as mercury. Established thermal methods are ex-situ based techniques that can operate from central or mobile facilities.

Thermal process can be either one or two stage processes, these are:

- **Incineration,** is a one stage process where heat is applied directly to the contaminated soil and organic contaminants are combusted within the soil matrix.

[17] The Warren Springs Laboratory was a research establishment (it is now a part of AEA Technology) that carried out research work for the DoE and the NATO/CCMS pilot study on contaminated land. Much of the work relating to the development of advanced techniques for the remedial treatment of contaminated land in the United Kingdom was undertaken at the Warren Springs Laboratory, and much of it by Dr Paul Bardos (Bardos 1991; Bardos 1994a; Wood and Bardos 1994; Martin & Bardos 1996).

- **Thermal desorption,** is a two stage process where organic contaminants are volatilised in a relatively low temperature chamber and then combusted in a second chamber.

Incineration processes produce a slag or ash as a treatment residue while thermal desorption produce a residual material which is still soil-like.

Table 33: Potential Advantages and Disadvantages of Thermal Treatment Techniques

Potential Advantages: Offers the prospect of the complete destruction of organic contaminants Relatively insensitive to particle size and distribution, although fine-textured soils may require pre-treatment Uses well established techniques Mobile plant available Re-use of treated soils may be possible depending on applied temperatures
Potential Disadvantages Cost greatly increased by high soil moisture content Applicability limited by temperature regime Some methods are highly energy intensive Contaminated material may require pre-treatment to reduce moisture content or screen out debris Control over atmospheric emissions required Metals are not destroyed although volatile metals may be removed Health and safety Approval by regulatory authorities may be needed for operation of mobile plant

Physical Treatment Techniques

Physical treatment techniques separate contaminated and uncontaminated material by exploiting differences in physical properties, by applying physical force or by altering physical characteristics to enable separation. Physical techniques can be used to treat a wide variety of organic and inorganic contaminants under a variety of site conditions. Established physical techniques include in-situ and ex-situ approaches that can either operate from central processing facilities or on-site from mobile facilities. Establishes techniques include:

- **Soil venting,** which **includes Soil Vapour Extraction** (SVE) and **steam stripping** to separate volatile contaminants from soils by encouraging volitilisation. This off-gas is treated above-ground.

- **Soil Washing,** which exploits the size, density, chemistry and magnetic differences between contaminants and soil. Soil washing relies on the favourable distribution of contaminants , for example by particle size, and results in the production of a concentrated contaminant fraction.

- **Physico-chemical washing** are the combination of soil washing and chemical leaching or extraction to enhance removal from soil fractions. Chemical leaching relies on the transfer of contaminants from the soil into an aqueous solution, possibly with the aid of chemical reagents such as surfactants, acids or alkalis.

Table 34: Potential Advantages and Disadvantages of Ex-situ Physical Treatment Techniques
Potential Advantages: Uses existing, well established technologies and equipment Reduced the bulk volume of contaminated material subsequent to treatment or disposal Applicable to a wide range of contaminants Mobile plant available
Potential Disadvantages Produce secondary waste streams for disposal or treatment Generally difficult to apply to peaty of clay soils Use of some solvents will have health and safety implications Regulatory approval may be needed for operation of the plant

Table 35: Potential Advantages and Disadvantages of In-situ Physical Treatment Techniques
Potential Advantages: Can be used in conjunction with biological processes Can be used in sites where little space is available for on-site treatment facilities In-situ techniques create less disruption and pose less of a nuisance SVE can be beneficial to soil structure and fertility In-situ techniques do not require the excavation of contaminated soils
Potential Disadvantages In-situ techniques create uncertainties in relation to accessibility of contaminants Technique is only applicable to volatile and some semi-volatile organic contaminants Difficulties in treating low permeability soils, soils with a high moisture content or high organic content Air emissions may require authorisation or further treatment

Solidification and Stabilisation Treatment Techniques

These techniques immobilise contaminants through physical and chemical processes. Solidification involves the addition of chemical reagents to contaminated soil and results in the formation of a solid mass. Contaminants are held in a matrix by physical encapsulation which reduces their availability. In contrast, stabilisation techniques use chemical reagents which react with the contaminants to transform them into an immobile form. While solidification can improve the physical characteristics of a soil stabilisation does not. However, in practice there is some overlap between the effects of solidification and stabilisation techniques. Vitrification is a solidification technique that can also be considered a thermal technique. Examples of these techniques are described below:

- **Cement and Pozzolan-based techniques** can be applied in-situ or ex-situ. Cement has been used for many years to solidify hazardous waste. Pozzolans are material that contain active silicates of aluminates which react with lime in the presence of water to provide a stable material. In-situ approaches involve the use of soil mixing equipment or high pressure water jets. The technique forms columns that can be overlapped to form a continuous mass. Ex-situ treatments that can

involve mixing the contaminated soil in a similar way to conventional concrete or by mixing on the ground surface or in place or in drums in which the waste is finally encapsulated.

- **Lime based Techniques** are used to stabilise contaminants with or without the addition of pozzolans. In the presence of pozzolans lime is used to stabilise contaminants. Lime is commonly used by directly mixing it with contaminated soil either on the surface of a site or in adapted concrete mixing equipment. Contaminants are encapsulated in a solid calcium hydroxide matrix.

- **Vitrification** is an ex-situ treatment technique which has also been demonstrated in-situ. It can also be considered a thermal technique. The technique involves the application of heat to melt contaminated soils and form a glassy material. The vitrification process destroys organic contaminants and encapsulates non-organic contaminants in the glassy matrix.

Table 36: Potential Advantages and Disadvantages of Solidification/Stabilisation Treatment Techniques

Potential Advantages:
Proven for certain inorganic contaminants
Formulations are available for the treatment of both inorganic and organic contaminants
Ex-situ methods are relatively simple to apply
Short treatment period
May improve the engineering properties of the ground
Mobile plant available
Can make transport and containment safer
Potential Disadvantages
Contaminants are contained rather than destroyed or removed
Ex-situ applications rely on good mixing
In-situ applications rely on good mixing and penetration
Requires long-term monitoring to check performance
Effectiveness may be reduced for certain matrix types due to mixing limitations
Heat is generated by some processes resulting in gaseous emissions
Some contaminants, particularly hydrocarbons, interfere with setting and hardening processes
Regulatory approval may be needed for operation of the process
Doubts over long-term leachability under field conditions

Biological Treatment Techniques

The majority of biological techniques rely on biological degradation to destroy organic soil contaminants. The extent of degradation achievable depend upon the chemical composition of the contamination, the micro-organism involved and the prevailing chemical and physical condition in the immediate soil environment.

Established biological treatment techniques include both in-situ and ex-situ techniques. Ex-situ methods include:

- **treatment bed techniques,** where contaminated soil is excavated and either: mixed with soil on the ground surface as in landfarming; placed into elongated heaps and augmented with materials such as

wood chips or compost to aid aeration; or, placed in static heaps or biopiles where nutrients and oxygen are added along a network of internal galleries.

- **Bioreactors,** where pretreated soils are slurried with water and treated in a purpose built reactor on a batch process. Within the reactor controls on temperature, pH, nutrients and oxygen supply can be amended to gain maximum contaminant degradation rates.

In-situ approaches are generally concerned with the optimisation of subsurface soil conditions to promote biodegradation. This can involve the addition of inorganic nutrients and oxygen if it is considered that a lack of these is rate limiting. **Bioventing** involves increasing the supply of oxygen and nutrients to the soil by injection or augmented with vacuum pumps which crated an extraction gradient towards extraction wells. **Bioremediation** involves the stimulation of biodegradation through the addition oxygen and nutrients in the aqueous phase.

Established biological treatments have been ranked according to their degree of process controll as follows:

bioreactors> biopiles> windrow turning> landfarming> in-situ bioventing> in-situ bioremediation.

Table 37: Potential Advantages and Disadvantages of Biological Treatment Techniques

Potential Advantages: Offers the potential for the complete destruction/detoxification of contaminants High contaminant specificity is possible Applicable to most matrix types provided good soil, mixing takes place Can be used in-situ in combination with methods such as SVE Simplest variants have modest operational requirements making them economical
Potential Disadvantages Some process variations require long treatment periods Many complex organic compounds and most common inorganic contaminants are not amenable to biological treatment Close monitoring of the system is required to maintain optimal conditions Regulatory approval may be needed for operation of the process Intermediate products and residues may have health and safety or environmental implications Commonly encountered contaminants may inhibit bacterial degradation

hemical Treatment Techniques

Chemical treatment techniques utilise a range of chemical reactions to destroy, transform or immobilise soil contaminants. In addition, chemical can mobilise contaminants into a liquid phase for further treatment or disposal. Chemical treatments which use a liquid phase to mobilise soil contaminants are often combined with physical treatments such as soil washing.

Chemical techniques include both in-situ and ex-situ approaches and may be further classified as extractive or destructive treatments. Extractive techniques commonly use transfer contaminants to a liquid medium (the

leachant) for subsequent disposal. The liquid used could be: an aqueous solution augmented with surfactants, acids or alkalis; an organic solvent or a supercritical fluid. The majority of inorganic contaminants are not amenable to destructive techniques so chemical treatments can be use to reduce the solubility and availability of inorganic contaminants, although such reactions can be reversible. Consequently, assessing the performance of these techniques can be difficult in relation to guideline values based on soil concentrations.

Ex-situ chemical treatments usually rely on the use of chemical engineering plant or chemical reactors including:

- **Activated Carbon Adsorption** where liquids or gasses are passed over activated carbon which has been treated to enhance its adsorption capacity. Contaminats are reversibly adsorbed to the surface and can be liberated by applying steam, heat or solvents and can be treatd.

- **Air stripping** of volatile contaminats involved bubbling air through a stream of water.

- **Floatation** involves bubbling air through water in a tank. Contaminants in flocs attach to the bubbles and float to the surface where they are skimmed.

In-situ techniques use a variety of approached including:

- Mixing of chemical reagents into the soil surface using conventional techniques such as ploughing; and

- Use of an aqueous-based delivery system including percolation and collection using near surface horizontal galleries and a pump and treat system. These techniques are variously described as **soil flushing** or **in-situ soil washing.**

Table 38: Potential Advantages and Disadvantages of Chemical Treatment Techniques
Potential Advantages: High degree of chemical specificity possible Applicable to a wide range of matrix types provided good mixing/contact is achieved
Potential Disadvantages Chemical reagents, intermediates and by-products may have public health implications Regulatory approval may be needed for operation of the process Substances may be present in the matrix which interfere or immobilise chemical reagents Effectiveness depends on good contact between reagents and contaminants

8.6.3 Operational Requirements for Treatment techniques

Ex-situ Treatment Techniques

General site requirements for on-site ex-situ treatment techniques vary depending on the technique in use. All ex-situ techniques will require excavation equipment and pre-treatment equipment to some extent. This depends on the requirements of the technique. In addition to screening to remove debris, Table 39 outlines what additional plant and pre or post treatment techniques also commonly required.

Table 39: Operational Requirements of Treatment Techniques
Thermal Treatment Techniques Thermal treatments may require dryers if soil moisture content is too high Post treatment units such as gas scrubbers may be required Mobile incinerator plant
Physical treatment Techniques Mobile soil treatment plant Storage for leachants or chemical reagents
Solidification/Stabilisation Treatment Techniques Mobile batch mixing plant Slurry preparation units
Biological Treatment Techniques Mobile biological reactors Soil mixing equipment
Chemical Treatment Techniques Mobile chemical treatment plant Storage for leachants or chemical reagents

Depending on the amount of equipment required, which depends upon the need for screens crushers, dryers and those requirements detailed above, ex-situ treatment techniques are reported to require between 0.5 and 2.0 hectares for operation. In addition to this, most techniques will require space for screened material to be stockpiled prior to treatment. Further requirements include:

- Access to the site by road as most mobile plant is transported by lorry or on trailers; and
- Site utilities including electricity and water.

The quantity of contaminated soil which can be treated by ex-situ techniques depends upon the capacity of the particular process but is also influenced by the type of soil being processes. Soils with clay contents much above 30% can prove difficult to handle. This can make it necessary to pre-treat the soil by breaking up the clods prior to treatment. Soils with high moisture contents can also pose problems for treatment techniques and necessitate drying prior to treatment. All techniques require careful screening to remove debris but may also require mixing with clean, dry or granular material to create a feedstock suitable for handling or processing. Such requirements reduce the operational efficiency of treatment techniques and reduce speed at

which treatment can occur. Further illustrations of the specific requirements and capabilities of ex-situ treatment techniques include:

- Mobile thermal treatment plant can process up to 100 tons per day but this will be less if much pretreatment is required for screening debris, breaking clay clods or reducing moisture contents. The technique is unlikely to be economic for volumes of soil below 10,000 tons.

- Ex-situ physical treatment techniques become uneconomic if the soil clay content rises above approximately 30 – 40%. Treatment facilities can treat up to 100 tons of soil per hour and are economical for small (<1,000 tons) as well as large volumes of soil. Methods which require the spreading or heaping of excavated soil require a larger surface area that for in-situ techniques.

- For biopiles or windrows a figure of $1m^2$ per $1m^3$ is assumed by some contractors. Slurry phase treatment can be carried out on-site lagoons or in the case of a mobile bioreactor, an area of 1ha is assumed including the need for pretreatment processes. Treatment times for biological techniques can range from months to years. Furthermore, biological techniques can be affected by climatic conditions. For slurry phase biotreatment a range of 9 to 45 days per batch has been reported, depending on batch size and contaminant concentration. Typical treatment capacities are 1 to 5 tons per hour. For other biological treatments treatment times can range from a few months to years. The time is dependant on climate, the size of treatment batches and contaminant concentrations. It is clear that ex-situ techniques are quicker than in-situ techniques.

In-situ Techniques

In-situ treatment techniques have similar requirements to ex-situ techniques in that they require road access and site utilities such as electricity and water. However, they typically require less space for engineering plant. In-situ SVE and bioventing require approximately $100m^2$ for the installation of equipment such as vacuum pumps and air blowers. However, access to the surface of the site is still required for the installation of injection and extraction wells. SVE, for example, requires access to the entire area which is to be treated so vacuum extraction wells can be installed on close (2 – 5m) centres.

For in-situ soil washing or soil flushing, plant and equipment will be required for: infiltration and collection systems; aqueous leachant preparation; injection and abstraction wells; effluent treatment plant; and, monitoring systems.

For in-situ techniques, volatile organic contaminants may be released directly from exposed soil or from extracted groundwater during treatment. Drainage measures will be required to prevent surface run-off from operations reaching surface water bodies.

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