THE HIGHWAYS AGENCY HA 73/95

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF THE ENVIRONMENT FOR
NORTHERN IRELAND

Site Investigation for Highway Works on Contaminated Land

Summary: This Advice note gives guidance to engineers responsible for planning and undertaking site investigations for trunk roads including motorways, on contaminated land.

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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HA 73/95

SITE INVESTIGATION FOR HIGHWAY WORKS ON CONTAMINATED LAND

Contents

1. INTRODUCTION

General

1.1 It is common for new highways, or highway improvement schemes, to cross land that has been disturbed or influenced by a previous or current use of the land. Certain uses of land may give rise to the presence of substances that may pose a hazard to human health, have a deleterious effect on water resources or be aggressive to highway structures constructed on the site. With regard to human health and safety there are particular risks for operatives undertaking site investigation on such sites.

1.2 In view of the risks to persons, natural resources and materials posed by contaminated land, there are additional requirements for site investigations of highway works on potentially contaminated land, both in their design and implementation.

1.3 This Advice Note complements HA34 (DMRB 4.1.2) "Ground Investigation Procedure" which should be read in parallel with this document. Section 4.16 "Fill, Waste and Contaminated Land" is superseded by this Advice Note.

1.4 Guidance in this Advice Note complements the certification system for ground investigation detailed in HD22 (DMRB 4.1.2). Separate certification procedures currently operating in Scotland are being retained for a further period and the references to the Preliminary Sources Study Report in this Advice Note do not apply in Scotland.

Scope

1.5 The purpose of this document is to provide guidance to Design Organisations, to enable them to plan and carry out safe, economic and appropriate site investigations for highway works on contaminated land, with minimum impact on the environment.

1.6 This Advice Note specifically addresses the environmental aspects of site investigation. However, in addition to the hazards posed by contamination, the physical condition of the ground that is affected may also present engineering problems of stability and compressibility. Guidance in respect of the suitability of various standard investigation techniques to contaminated ground is given in Chapter 8 of this document, whilst general guidance on planning and execution of site investigations to establish engineering properties is given in HA34 (DMRB 4.1.2).

Implementation

1.7 This Advice Note should be used forthwith for all schemes currently being prepared provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation.

2. DEFINITIONS

2.1 Terms listed in Section 3 (Definitions) of Advice Note HA34 also apply in this document. The following additional definitions apply to terms used only in this document.

2.2 Potentially Contaminated Sites are those areas of the whole route corridor of the highway scheme which are identified during the desk study as possibly containing substances in the ground that could give rise to hazards likely to affect human health, the natural environment or the proposed development.

2.3 Significant Sites are Potentially Contaminated Sites which the Design Organisation qualitatively assesses may have an effect on the proposed highway scheme. The qualitative assessment methodology is described on Figure 3/2.

2.4 On-line Sites are Potentially Contaminated Sites which are partly (or wholly) within the possible future fence lines of the highway.

2.5 Off-line Sites are Potentially Contaminated Sites beyond the possible future fence lines of the highway.

2.6 Contamination Ground Investigation (CGI) is an investigation carried out on a Potentially Contaminated Site to obtain information needed to assess the significance of the contamination of the site. The CGI is often combined with geotechnical ground investigation work also required on the Potentially Contaminated Site.

2.7 Hazard is a substance or situation with the potential to cause harm.

2.8 Risk is the probability of the harm from a particular hazard being realised.

2.9 Sensitive Receptors (or targets) are humans, flora, fauna, resources or the proposed highway construction which may be adversely affected by the presence of a ground hazard during site investigation, highway construction or subsequent operation of the highway.

3. GENERAL CONSIDERATIONS

Introduction

3.1 The construction of a highway scheme over contaminated land can represent a beneficial use of land, provided that the works are appropriately designed, constructed and maintained. Highway schemes represent one of the least sensitive uses of contaminated land.

3.2 Site investigations for highway schemes may cross isolated areas of contaminated land, or may be wholly on land that is potentially or actually contaminated. Due to the linear nature of most schemes, it is usual for potentially contaminated ground to occupy only part of the total highway site.

3.3 Site investigation for a highway scheme usually involves a staged approach. The initial stage of site investigation work is undertaken during the route appraisal phase of the scheme and comprises a preliminary sources study of the route corridor(s). This involves a detailed desk study and site reconnaissance (walkover survey). The need or otherwise for a preliminary ground investigation would be identified at this stage.

3.4 Further stages of site investigation are normally undertaken during assessment of the preferred route alignment, and will involve main ground investigation, with a possible requirement for supplementary ground investigations depending on the outcome of any public inquiry.

Significance of Ground Contamination

3.5 All aspects of the planning, performance and reporting of a site investigation are affected by the potential (and actual) presence of ground contamination. Ground contamination may have a significant influence on the design and cost of that part of the scheme which is affected. Where heavily contaminated sites are present consideration may need to be given to altering the vertical or horizontal alignment of the scheme.

3.6 The principal impacts of contaminated land on highway design and construction (in addition to the engineering characteristics of the ground) are:

(i) Hazards to health and safety of the workforce and general public during site investigation and road construction;

(ii) Hazards to highway structures and materials through chemical effects on materials;

(iii) The generation and disposal of contaminated groundwater during ground investigation, during construction and in the permanent works;

(iv) Limitation in the re-use of excavated materials in other parts of the scheme due to the possible leaching of contaminants and effect on water resources;

(v) The toxic effects of certain contaminants on plants restricting the re-use of excavated materials for landscaping;

(vi) The disposal of unacceptable material Class U2 as defined in the Specification for Highway Works (4);

(vii) Imposition of constraints on the future maintenance of the highway due to the presence of barrier layers, venting trenches, contaminated groundwater, soil gas etc.

3.7 The principal impacts on the ground investigation process concern:

(i) The need to plan and implement appropriate health and safety precautions to protect both site investigation personnel and the general public during the execution of field sampling and laboratory testing;

(ii) The possible need to carry out a preliminary phase (or phases) of contamination investigation in advance of the main ground investigation;

(iii) The protection of surface and groundwater resources from the discharge of contaminated water or leachates arising from the investigation, or from the creation of pathways through aquicludes by drilling and boring techniques;

(iv) The possible requirement for additional sampling locations and/or alternative sampling and monitoring techniques;

(v) The need to employ strict sampling, sample handling and testing protocols to ensure reliable results;

(vi) The need to employ suitably qualified and trained staff experienced in investigation of contaminated ground; to plan, direct, execute and monitor the investigation.

(vii) The need to make special arrangements for disposal of contaminated arisings and unused sample material.

Types of Sites

3.8 Land may be subject to ground contamination arising from a wide range of activities carried out either on the land, or on adjacent areas. Contaminative activities include burial or surface deposit of wastes, spills or leaks of noxious liquids, excessive application of agricultural chemicals and emissions to air of hazardous dusts by accident or intention.

3.9 Ground contamination is common within urban and industrial areas. In such areas multiple point sources of contamination may be present. In rural areas there may be diffuse contamination arising from agricultural operations, or more isolated point sources.

3.10 The types of sites where contamination of the ground is most likely include:

(i) Waste disposal sites, and land surrounding these sites;

(ii) Sites of heavy industry (eg steelworks, ship building etc), and gas works sites;

(iii) Chemical plants and manufacturing plants, particularly those using or storing bulk liquid chemicals, discharging significant quantities of effluent or producing hazardous solid wastes;

(iv) Sewage farms and sewage treatment plants;

(v) Breakers yards, scrap yards, timber treatment works, railway sidings;

(vi) Fuel storage facilities, garages and petrol station forecourts;

(vii) Areas of fill (made ground);

(viii) Former mining sites and associated areas of waste disposal.

Appendix A provides a list of potentially contaminative uses of land and the likely contaminants associated with those uses.

Nature of Ground Contamination.

3.11 Chemical contamination of the ground may occur in one or more phases. It may be present in solid form (eg industrial residues or products, mining wastes etc.); it may occur in liquid form (dissolved, entrained and/or floating on the groundwater, or within the partly saturated zone) or it may occur as gases (eg methane or volatile organic vapours within the partly saturated zone, or entrained or dissolved in the groundwater). It is common to find that the groundwater is affected where a solid source of contamination is present. Likewise, chemical contamination may adsorb to the soil particles when liquid chemicals are spilt on the ground, or a plume of contaminated groundwater passes through the ground. Toxic or explosive soil gases may be present in the ground as a result of microbial decomposition of solid or liquid constituents of the ground, by migration from adjacent areas or spills of volatile liquids.

3.12 A wide range of potentially harmful substances may occur in the ground. Commonly encountered contaminants, and the principal hazards they produce are given in Table 3/1 below. Certain harmful substances may occur naturally as well as being present as a result of man's contaminative activities.

3.13 Significant radioactive contamination is generally uncommon. Principal sources include facilities handling hospital and laboratory waste and factories using radium luminescence (for example in the manufacture of World War II vehicle and aircraft instruments and of watch faces). The detection of ionising radiation requires specialist equipment with appropriate interpretation. If significant radiation is detected, special procedures are required as radioactive materials are the subject of specific legislation (Radioactive Substances Act 1993 and The Ionising Radiation Regulations 1985).

TABLE 3/1
TYPES OF CONTAMINANTS AND HAZARDS

Types of Contaminant		Principal Hazard
INORGANIC		
Metals	Toxic e.g. cadmium, lead, arsenic, mercury.	May be harmful to health of humans or animals if ingested, inhaled or through skin contact.
	Phytotoxic metals e.g. copper, nickel, zinc	May restrict or prevent plant growth. Some salts of these may also be toxic to humans and animals.
Non-metals	Toxic e.g. cyanides	May be harmful to health of humans or animals if ingested, inhaled or through skin contact.
	Corrosive sulphates, chlorides, acids, alkalis	May lead to deterioration of construction materials e.g. concrete structures. Some are also irritants.
Minerals e.g. asbestos		Harmful to health: potential respiratory diseases.
Gases e.g. carbon dioxide, hydrogen sulphide		Some may be toxic to humans. May cause asphyxiation in confined spaces.
ORGANIC		
Solids e.g. coal and coke dust		Underground fires.
Liquids	Light, e.g. solvents	Many are highly flammable and toxic.
	Heavy, e.g. oils and tars, phenols, polyaromatic hydrocarbons	Contamination of water supplies. Deterioration of buried services. May be carcinogenic. Some are flammable producing toxic fumes.
Gases e.g. methane, volatile organic compounds		Flammable/explosive. May cause asphyxiation in confined spaces. May be carcinogenic.
BIOLOGICAL		
Pathogens e.g. bacteria, viruses (such as foot and mouth, anthrax), parasitic eggs or cysts		Harmful to health of humans or animals

Approach to Site Investigation

3.14 The approach to the identification and investigation of contaminated land on highway schemes is outlined below and illustrated on flow diagrams, Figures 3/1 and 3/2. More detailed advice of the work involved in each step of the investigation is given in the subsequent chapters.

3.15 The first step is the identification of potentially contaminated sites within the study area for the proposed scheme. This is carried out during the initial part of the desk study phase of the project and involves an extension of the research undertaken to establish geotechnical conditions.

3.16 As potentially contaminated sites are identified, a qualitative assessment is made of the potential significance of each site to the proposed scheme. Sites of significance are those for which there are risks which may affect the highway works. The assessment should take into account whether or not the ground will be physically disturbed by the highway works, the nature and degree of potential contamination, the geological conditions, the hydrological regime and the environmental sensitivity of the local area. The assessment leads to identification of on-line and off-line sites within the study corridor which are significant (i.e areas of potentially contaminated ground which may potentially affect the proposed scheme). Figure 3/2 illustrates a flow diagram of the decision process for assessing site significance.

3.17 For significant sites with the potential for substantial environmental effects and/or cost implications, it is advisable to conduct a preliminary contamination ground investigation as part of the preliminary sources study. This preliminary ground investigation would generally only be necessary for on-line sites where there are high risks of substantial hazards being present.

3.18 A contamination ground investigation will be required during the main ground investigation to assess the implications of each significant potentially contaminated site. Ground investigation on off-line sites will only be required in exceptional circumstances. However, on-line areas potentially affected by migration of gas or leachate from these off-line sites should be investigated. The Design Organisation must make a judgement as to the extent of the on-line area that might be affected by this migration.

3.19 Prior to any ground investigation on potentially contaminated land, the Design Organisation should carry out a qualitative assessment to determine the degree of risk (to humans and the environment) involved in conducting the investigation. This risk assessment, undertaken on the basis of the available desk study information, is described in Chapter 6. A 'low risk', 'moderate risk', 'high risk' categorisation is recommended for the Design Organisation's use to facilitate planning and organisation of the ground investigation.

3.20 A single phase of combined contamination and geotechnical investigation is usually appropriate for low risk sites, although the requirements for chemical and geotechnical data should be considered independently when designing the ground investigation.

3.21 For moderate risk sites the contamination and geotechnical ground investigation may be undertaken within the same contract. However, the contamination investigation should, if possible, be phased to occur separately within the early part of the contract in order to identify and minimise risks.

3.22 For high risk sites, the contamination investigation should be carried out in stages with a preliminary stage carried out in advance of the main ground investigation contract. The preliminary investigation may be undertaken at the route assessment stage, as mentioned in paragraph 3.17.

3.23 Risk assessment principles, which are described in Chapter 6 in the context of the design of the ground investigation, should also be applied in the assessment of investigation results. Further guidance on risk assessment and its role in site investigation is given in Chapters 2 and 3 of the Institution of Civil Engineers Design Guide on Contaminated Land (28).

Environmental Assessments

3.24 The guidance set out in Volume 11, Section 3, Part 11 of the Design Manual for Roads and Bridges should be followed for all schemes which require Environmental Assessment, including all trunk roads and motorways. This establishes the need for potential hazards to be identified and for the risks on potentially contaminated land to be confirmed by means of site investigation. A three stage approach is described in parallel with the staged approach to road and bridge design:

1) During appraisal of route corridors, possible constraints should be identified through liaison with local authorities and other relevant statutory organisations.

2) During route assessment, sites posing a

constraint should be identified. "Where an area of contaminated land may be affected, consideration should be given to the need for site investigation work at this stage".

3) For the final stage, the significance of any constraints should be identified. Steps to be taken include "to undertake a site investigation of any contaminated land to establish the contaminants present and identify the method of treatment".

The results of contamination ground investigation are thus needed for both the engineering design of the highway works and for the environmental impact assessment.

Sources of Reference

3.25 General guidance on the development of contaminated land is provided by a number of publications (5, 6, 7, 8, 9, 10, 11, 12) produced by the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL). The general reference for site investigation practice is the British Standard Institution (BSI) publication 'Code of Practice for Site Investigations', BS 5930 (13), which is currently under revision. The BSI Draft for Development 'Code of Practice for the identification of potentially contaminated land and its investigation', DD175:1988 (14), also provides useful guidance on sources of information.

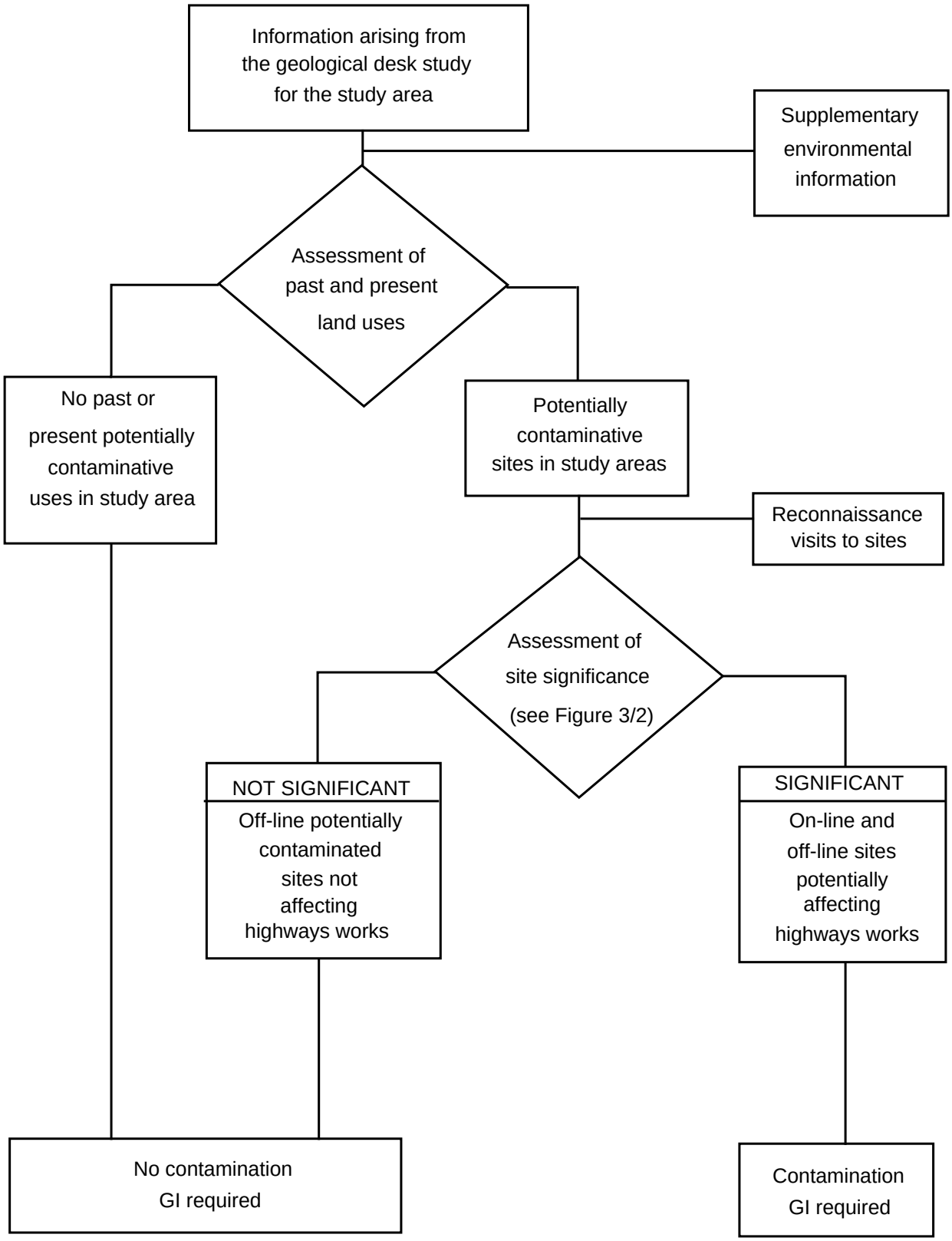

Figure 3/1. Flow diagram for assessing need for contamination ground investigation

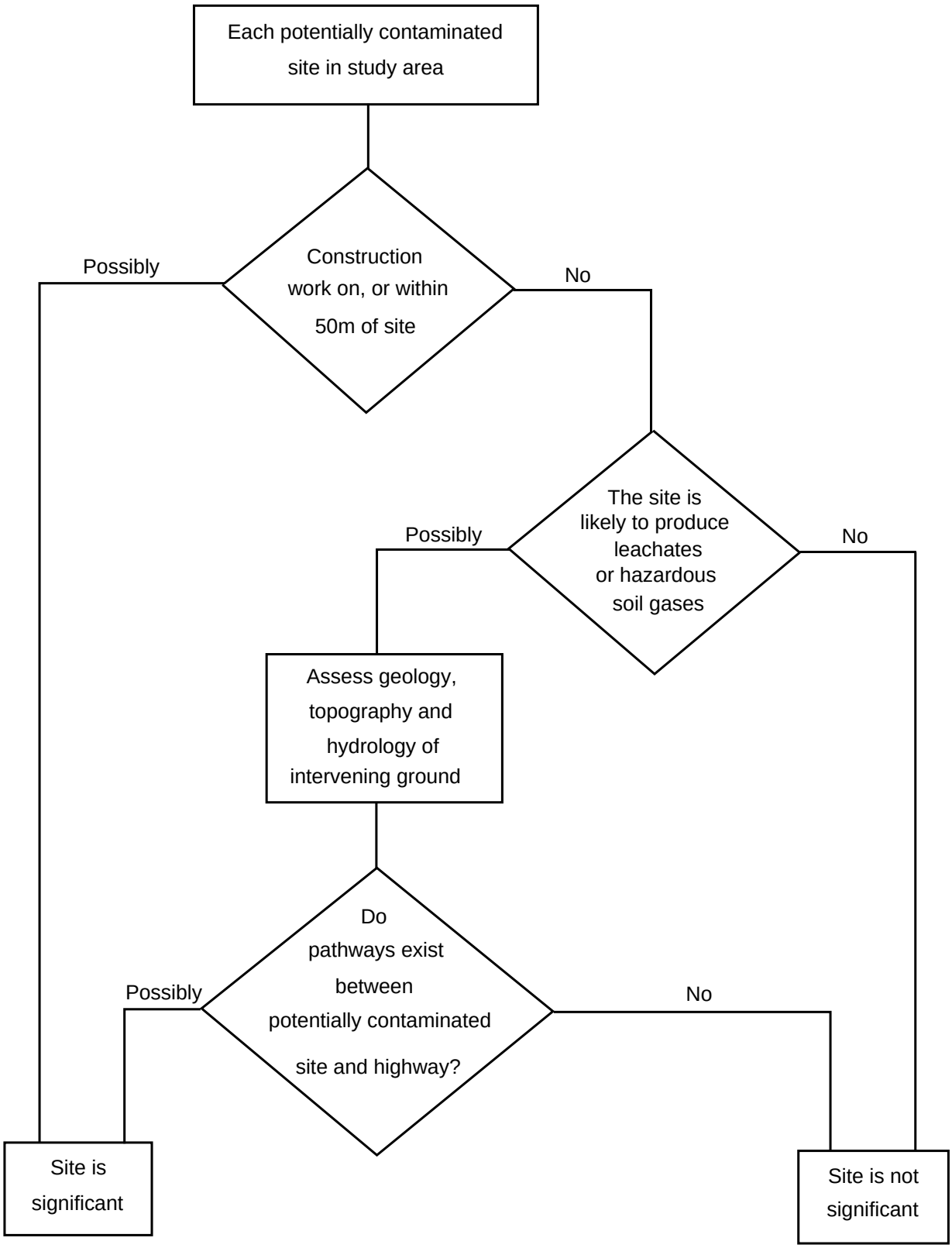

Figure 3/2. Diagram for assessing significance of potentially contaminated sites

4. DESK STUDIES

General

4.1 The desk study for a highway scheme, which results in the production of the Preliminary Sources Study Report, is described in Section 4 of HA34 and should be prepared in accordance with HD22. The desk study consists of a review of all sources appropriate to the scheme collected and presented according to TRRL Report LR403 (15) and BS 5930:1981 (13). An example of typical contents of the Preliminary Sources Study Report is given in HD22. The report should provide sufficient information to enable the appropriate design of subsequent ground investigations.

4.2 The assessment of the potential presence of ground contamination, based on existing information, is an important part of the desk study for all sites crossed or adjacent to land affected by the works. The presence of significant chemical contamination is usually associated with former or current industrial uses of land, though other activities (e.g. spills, fly tipping etc) may also give rise to chemical contamination.

4.3 Study corridors extending 500m either side of the proposed alignment alternatives should initially be considered when identifying potentially contaminated sites. This corridor width should be sufficient to include any significant effects of landfill gas and leachate migration from off-line sites. The topography and geology of different sections of a scheme are also important in determining the potential influence of off-line contamination sources. Accordingly, it may be appropriate to reduce or increase the width of the study corridor in some areas.

4.4 The identification of potentially contaminated sites in the study corridor(s) will require reference to current and past topographical maps, geological and hydrogeological maps, and aerial photographs as for any routine geotechnical desk study, following the guidance given in Section 4.1 of HA34. The principal objective of the desk study is to discover the location and history of sites with past or present uses which may have led to ground contamination.

4.5 In considering the previous uses of land, both the active and the post-active phases should be considered to determine the potential for contamination of the ground. Information relevant to the active phase could include details of type of development, products and by-products, storage locations. Information which should be sought for the post active phase includes details of waste discarded or remaining on site, re-development of land and local perceptions of the site.

Maps

4.6 Valuable information can be obtained by reference to current and previous editions of maps.

i. Ordnance Survey maps were first issued in 1804, though most first edition mapping dates from the 1860s and 1870s. Large scale mapping (6" to 1 mile and 1:2500 scales) show considerable detail and are of greatest interest. Ordnance Survey maps are available in most local archives and town libraries as well as at the British Library in London, the National Library of Wales in Aberystwyth, the National Library of Scotland in Edinburgh, the Bodleian Library in Oxford and the Cambridge University Library.

ii. Non-Ordnance Survey maps include early town plans, estate maps, parish tithe maps, fire insurance plans, mine maps and geological maps. These records can assist in determining the different developments and redevelopments on a site, as well as identifying the locations of structures and other features on the site.

iii. Plans and survey drawings of particular sites produced or held by present or previous occupiers are often particularly useful in indicating the disposition and use of particular buildings and areas, and describing the location of underground chambers or services.

Aerial Photographs

4.7 Aerial photographs provide a more detailed record of the landscape than topographic mapping and may be interpreted to provide quantitative as well as qualitative information. Most of Britain has been photographed on several occasions over the past 40 years, and coverage of many urban areas extends over the past 60 to 70 years. Stereoscopic pairs of aerial photographs of the study area for highway works can be used to provide a three dimensional image and may be of assistance in locating places where special attention is necessary thereby supplementing documentary and visual information obtained in other parts of the desk study. Further information on aerial photography and

photographic interpretation of geological features can be obtained by reference to TRRL publications LR 369 (17) and LR 1085 (18).

4.8 Aerial photographs of Great Britain are held either by the Ordnance Survey, other Government agencies or by the commercial companies who flew the survey. Appendix B lists a number of major sources of vertical aerial photography. Initial enquiries should be directed to the relevant Government agency to ascertain where photography relevant to the highway scheme is held. Applications can then be made to the appropriate organisation for purchase of the photography.

Documentary Resources

4.9 Records may be available from current and previous landowners for certain sites affecting the route. These records may include plans, details of processes undertaken on site, materials handled and chemicals used, and previous site investigation data. Information from ground investigations carried out in the general area often yields little or no quantitative data of relevance to assessment of potential contamination, but their content should be checked. Contact with the Overseeing Organisation should be made when checking whether information relating to highway schemes in the area is available. Factual reports may provide useful information on ground conditions but interpretative reports from these investigations should be independently assessed by the Design Organisation.

4.10 Apart from site specific reports, other documentary resources may provide background or contextual information. Trade directories, Government and Municipal Records, investigative commissions, professional journals and other documents may provide useful information. Further guidance on documentary research is given in a Department of the Environment research report (26).

4.11 Authorities such as the Health and Safety Executive, the Waste Regulation Authorities and Her Majesty's Inspectorate of Pollution (Her Majesty's Industrial Pollution Inspectorate in Scotland) may be able to help identify previous industrial users. Table 4/1 lists authorities who may provide information of relevance for the desk study. If the names of previous site occupiers can be obtained then they may be approached for information regarding processes undertaken on site.

Statutory Authorities

4.12 Statutory authorities should be contacted during the desk study not only to obtain relevant information, but also to establish any requirements or limitations to the subsequent ground investigation. The relevant authorities who may have requirements affecting the ground investigation can include the Waste Regulation Authority, the Health and Safety Executive and the Local Authority's Environmental Health Department. For example, in England and Wales, permission must be sought from the National Rivers Authority prior to drilling into aquifers or discharging water into surface watercourses.

Collation of Data and Identification of Potentially Contaminated Sites

4.13 Information concerning sites affected by the highway route should be collated during the preliminary stages of the desk study so that as the desk study progresses, potential hazards associated with those sites are identified. At the same time any needs for further information should be identified.

4.14 The results of the desk study of ground contamination, including information obtained in the Site Reconnaissance (Chapter 5), should be compiled and incorporated with the geotechnical information within the Preliminary Sources Study Report. This information can then be used to develop recommendations for subsequent ground investigation. Some information from the report will also be useful for the environmental assessment of the scheme.

TABLE 4/1
STATUTORY AUTHORITIES HOLDING INFORMATION RELEVANT TO GROUND CONTAMINATION DESK STUDIES

AUTHORITY	INFORMATION
Local Authority - County Councils (England and Wales) - District Councils (Scotland)	Waste disposal departments will hold site licences and licence applications for waste disposal sites. Site specific information on the ground conditions and details of landfills may also be available.
Local Authority - Metropolitan Borough Councils - District Councils - Regional Councils	Environmental Health Departments will hold details of licensed waste disposal sites, active industrial sites with prescribed processes and a register of scrap metal dealers. They may also have compiled information on potentially contaminated sites and may hold site specific information such as gas monitoring data, infra red or thermographic imagery. Planning Departments will be able to provide information on the planning history of the site and planning application details.
National Rivers Authority (England and Wales) River Purification Board (Scotland)	The National Rivers Authority has special responsibility for protection of controlled waters in England and Wales. This role is undertaken by the River Purification Board in Scotland. Details can be provided of abstraction licences, surface and groundwater quality data, and may be able to provide information concerning any known sources of contamination in the area affected by the highway scheme.
Water Companies (England and Wales) Regional Council Drainage Department (Scotland)	These will have details of sewage treatment facilities located near highway schemes, which may be contacted for details of sludge disposal activities. Discharge consents may also be available for industrial sites, which will give an indication of liquid wastes handled.
Ministry of Agriculture, Fisheries and Food. Department of Agriculture and Fisheries (Scotland)	Regional and local offices may have knowledge of burial grounds for diseased animals, tanneries and slaughter houses.
Her Majesty's Inspectorate of Pollution H.M. Industrial Pollution Inspectorate (Scotland)	Has records of premises regulated under Radioactive Substances Act 1993 and details of scheduled industrial sites.

5. SITE RECONNAISSANCE

5.1 During the course of the desk study, a site reconnaissance visit (site walkover inspection) should be made to all the potentially contaminated sites affected by the route corridor. The visit should be undertaken to complement and supplement documentary information collected during the desk study, and to assist in the planning of subsequent ground investigations.

Timing

5.2 Reconnaissance visits of potentially contaminated sites should be undertaken after the background documentary information has been collected and reviewed. This is to enable appropriate health and safety measures to be taken by persons carrying out the site reconnaissance and to enable maximum benefit to be gained by as full a knowledge of the past uses of the site as possible.

Visual Examination

5.3 Potential contamination can be revealed by signs such as the presence of tanks and drums holding hazardous substances, waste storage areas, staining of the ground, polluted waters, vegetation distress and odours. Localised and distinctive changes in the appearance of crops and vegetation may indicate filled pits and quarries or other changes in subsoil conditions. Hazards may appear in various forms, including gaseous, liquid or solid phases.

5.4 Although visual examination of the surface of a site can provide valuable information, the absence of any sign of contamination does not indicate that the site is uncontaminated.

5.5 A record should be made of the site reconnaissance, noting all sites visited and listing any signs of potential hazards, locations of any wastes and evidence of suspect ground. Wherever possible, photographs should be taken of all areas of interest. The site reconnaissance may also be used to assess practical solutions to problems of access to sites and the presence of services for the ground investigation. There may be access problems for the contamination ground investigation in addition to those posed by standard ground investigations (for example in connection with decontamination units or safety measures). These need to be considered during the site reconnaissance.

5.6 It is useful to carry out the site reconnaissance in the company of persons familiar with the sites and with their current and former uses. In the case of sites previously under industrial use, this may involve a plant manager or safety officer. Farmers and other local residents will frequently yield useful information, although enquiries should be handled with sensitivity appropriate to the timing and phasing of the overall works.

Health and Safety

5.7 Special care should be taken to ensure health and safety during a site visit on potentially contaminated land, since the degree and extent of potential hazards have not been fully defined at that stage. Health and safety measures are discussed in Chapter 7. Personal protective clothing and equipment should be used as necessary, and hazards associated with skin contact are to be noted in particular. Confined spaces should not be entered on a site reconnaissance visit to a potentially contaminated site.

6. RISK ASSESSMENT IN THE DESIGN OF GROUND INVESTIGATIONS

Approach

6.1 Planning of investigations on potentially contaminated land should include a thorough assessment of the human health and environmental risks associated with alternative methods of conducting the investigation.

6.2 The assessment of risk involves an estimation of the likelihood of a hazardous effect being realised. For a risk to exist, there must be a hazard, a sensitive receptor (or target), and a potential pathway between the hazard and the receptor. For the purpose of designing ground investigations for highway works on a potentially contaminated area, qualitative methods of risk estimation represent a practical and generally sufficient approach.

6.3 The first step of the risk assessment procedure is the identification and characterisation of potential hazards on each potentially contaminated area to be investigated. This characterisation is undertaken by the desk study and site reconnaissance, and may also benefit from the results of previous ground investigations. The risk assessment should then identify possible targets for the types of hazards which may arise at each site. The potential targets at highest risk during ground investigations are usually the site operatives, although many other receptors need to be considered, as described in paragraphs 6.6 and 6.7. Finally, the risk assessment should consider the potential pathways between hazards and receptors which can then assist in determining the precautions and methods of work to be applied. Scenarios to be considered may be complex: for example, a ground investigation involving boreholes on a landfill site could affect the capping, perched water tables, natural containment and gas control system, allowing the release of one or more hazards which may affect human and groundwater receptors.

Hazards

6.4 The following activities give rise to the principal hazards posed by ground investigation:

(i) Exposing and/or bringing contaminated soils to the surface;

(ii) Allowing releases of contaminated groundwater;

(iii) Improperly disposing of contaminated soils arising from the exploration processes (boring and trial pitting);

(iv) Creation of new groundwater migration pathways by exploration activities or permanent installations;

(v) Temporarily storing contaminated soils on the ground surface;

(vi) Handling of soil and groundwater samples;

(vii) Creation of toxic or explosive gas mixtures in confined spaces; and

(viii) Creation of harmful dusts.

6.5 The hazards posed by different types of contaminants are outlined in Table 3/1 and are more fully described in the ICRCL document "Guidance on the Assessment and Redevelopment of Contaminated Land" (5) and CIRIA document "A Guide to Safe Working Practices for Contaminated Sites" (19).

Receptors

6.6 The human receptors that may be affected by site investigation works for highway schemes are principally:

(i) The ground investigation contractor's field personnel;

(ii) The supervising engineer's staff and approved visitors; and

(iii) The ground investigation contractor's laboratory staff.

Other persons that might also be affected include:

(i) The landowner, and other persons with permission to be on the land;

(ii) Trespassers onto the land;

(iii) Persons working, or passing close by the site;

and

(iv) Persons that might come in contact with samples taken from the site.

6.7 Non-human receptors that should also be considered in the risk assessment of the site investigation activities are:

(i) Farm animals and natural fauna;

(ii) Surface water courses (either directly, or indirectly via piped drainage systems);

(iii) Groundwater resources;

(iv) Natural vegetation and farm crops.

Pathways

6.8 The potential pathways linking ground contamination hazards to human receptors are skin (dermal) contact, inhalation of dust or toxic gas, and ingestion of soil particles. Human receptors are also sensitive to exposure to elevated levels of radiation that might be present in the ground.

6.9 Risk management techniques addressing pathways include the adoption of appropriate investigation and sample handling techniques, the use of appropriate protective clothing and the adherence to strict working practices. Further discussion of health and safety measures is given in Chapter 7.

6.10 The need for covering (or dampening down) of contaminated soils arising from trial pitting should be considered to reduce the potential risks of inhalation of harmful dusts by ground investigation personnel, site visitors, or members of the public on or off site.

6.11 The effectiveness of the health and safety measures in eliminating contamination pathways depends upon informing all persons involved in the work of the hazards present and of the particular measures that are required. Persons not involved with the work (eg the landowner) must also be advised of the potential hazards and any specific precautions necessary. Whilst it is difficult to control the actions of trespassers, all reasonable steps should also be taken to minimise the risks to such persons.

6.12 The risks to farm animals and natural fauna mainly arise from the surface conditions at the site following completion of the ground investigation. Pathways to such receptors are skin contact, ingestion of contaminated soil particles or plants, drinking contaminated water seeping from or accumulating on the ground, and inhalation of toxic dusts or vapours. The method of eliminating these pathways is the proper reinstatement of all exploration points including, when necessary, the provision of an adequate thickness of inert soil cover.

6.13 Pathways for contamination to reach surface water courses include disposal to a water course or surface water sewer of water arising from drilling or purging, run-off from contaminated soil exposed either temporarily or permanently at the surface by the investigation, and seepage of contaminated groundwater (or landfill leachate) from ground disturbed by the ground investigation process. Further advice on the impact of contaminated land on ground and surface waters is given in a research report sponsored by the Department of the Environment (25).

6.14 Groundwater quality can be affected by certain methods of ground investigation (especially boreholes), and by permanent installations (such as standpipes). This is particularly important where an overlying layer of contaminated ground is separated from an underlying aquifer by a low permeability layer which will be penetrated by the ground investigation borehole. Careful design and supervision of the investigation is necessary in such circumstances to avoid creation of vertical pathways.

Risk Classification

6.15 As described in paragraph 6.3, the first step in the risk assessment is the identification of hazards. It is recommended that an initial screening of the significant sites within the study area is made, and the sites classified into one of the following three categories:

High risk sites - with the potential for substantial hazards being present;

Moderate risk sites - with the potential for moderate level hazards being present;

Low risk sites - with low potential for significant hazards being present.

6.16 High risk sites are those known, or suspected to contain significant quantities of substances that may "seriously" affect human health. A wide range of chemicals and other substances might be present including toxic metals, organic compounds, asbestos, pharmaceutical and veterinary wastes, phenols, cyanides and medical products. The presence of flammable and explosive materials, radioactive substances, biological or bacteriological hazards, or particularly corrosive materials would also determine a high risk classification of the site. High risk sites would include landfills where hazardous wastes have been tipped, and areas of uncontrolled tipping.

6.17 Moderate risk sites are those assessed to contain potentially harmful substances in amounts or concentrations that might affect human health if reasonable precautions were not taken, but would not be life threatening. Within this category would be sites containing household and garden refuse, waste food, undiseased animal carcasses, rubber and latex, tyres, etc. Both moderate and high risk sites may be a source of landfill gas.

6.18 Low risk sites are defined here as those which are assessed to be contaminated with only small quantities or low concentrations of hazardous substances, or to contain mainly inert materials (e.g. glass, ceramic, concrete) that are not inherently hazardous to health although they may hinder works. Such sites would not be a source of landfill gas.

6.19 On sites for which little or no information is available, conservative scenarios should be considered. For example, an older landfill site in which uncontrolled tipping and indiscriminate dumping took place, may merit classification as a high risk site for the purposes of planning ground investigation.

6.20 The risks associated with site investigation on undisturbed land subject to migrating leachates or soil gases may be similar or substantially less than the risks in the source area of leachate or gases. Consequently investigations of on-line potentially affected land may have lower risk classification than the off-line source site, particularly when the distance is more than about 50 to 100m.

6.21 The Site Investigation Steering Group publication "Guidelines for the Safe Investigation by Drilling of Landfills and Contaminated Land" (19) also proposes a site risk classification, though the distinction in purpose should be noted. The classification in this Advice Note is to assist the Design Organisation in the planning stage of the investigation, including selection of investigation technique, phasing of the investigation, safety and personnel requirements. The classification in the Site Investigation Steering Group document is aimed at Contractors to assist in the adoption of appropriate health and safety measures on site. Contractors should carry out their own independent risk assessments.

7. HEALTH AND SAFETY

General

7.1 The desk study should identify the types of potential hazards. However, at the time the ground investigation is undertaken the degree of risk has usually yet to be determined. For this reason, great care must be taken with regard to the provisions for the health and safety of the investigation team when carrying out ground investigations on potentially contaminated sites.

7.2 Other health hazards, common to construction sites and laboratory work, must also be considered when carrying out ground investigations. General guidance on safe working practices for contaminated land is given in the CIRIA Publication "A Guide to Safe Working Practices on Contaminated Sites" (19), the HSE Publication "Protection of Workers and the General Public During the Development of Contaminated Land" (21) and the Site Investigation Steering Group document "Guidelines for the Safe Investigation by Drilling of Landfills and Contaminated Land" (20).

Legislation

7.3 Legislation in the field of health and safety is centred on the Health and Safety at Work Act (1974) which is an umbrella Act under which more specific Regulations, Codes of Practice and Guidance Notes have been issued. It details the duties of employers and employees concerning health and safety and indicates the general duties applicable to all work places.

7.4 Employers have a responsibility to protect employees from foreseeable risk of injury or death at work. For site investigations on contaminated land, this responsibility requires the provision of information and protective measures regarding potential hazards to safeguard operatives and others, on site. The site personnel should be given instructions on the nature of known and potential hazards.

7.5 In order to control the exposure of all persons to substances hazardous to health, the Control of Substances Hazardous to Health (COSHH) Regulations 1988 require a risk assessment to be carried out prior to start of work, and the provision of measures to control the assessed risk. COSHH assessments should be prepared by the contractor on the basis of his proposed method of work and the information revealed in the desk study and site reconnaissance. All relevant information should be made available to the contractor at tender stage, identifying the hazards likely to be found on site, so that the contractor may assess the risks and identify the special procedures and measures to be taken to minimise these risks. The COSHH assessment should lead to the preparation of control measures detailed in a Safety Plan (paragraphs 7.13 to 7.15), and these should be re-evaluated whenever there is a change of circumstances.

7.6 The Construction (Design and Management) Regulations 1994 place statutory duties upon clients, designers and contractors to ensure that health and safety is taken into account throughout all stages of a construction project.

Approach

7.7 The COSHH Regulations recommend the following approach to health and safety when dealing with substances hazardous to health:

(i) prevent exposure, where this is possible;
(ii) control exposure, where prevention is not possible.

7.8 The prevention of exposure is best achieved through choice of an investigation method that minimises the release of, and contact with hazardous substances. Other measures that may assist in preventing or controlling exposure include:

(i) use of monitoring equipment particularly for gases and radioactivity;
(ii) restriction of certain activities (eating, smoking and use of flames);
(iii) use of personal protective equipment (such as protective overalls, safety boots, gloves, dust masks and eye protection).
(iv) facilities for decontamination and washing - both for site operatives and for equipment and plant;
(v) facilities for proper disposal of contaminated materials;
(vi) use of communication equipment;

7.9 If unknown or suspicious substances are encountered during excavation of exploratory holes, work should cease until a specialist can confirm what the material consists of and whether a hazard exists. Likewise, should any site operative feel unwell, the individual responsible for health and safety should be informed immediately and should take prompt action.

Awareness and Training

7.10 All persons employed in the site investigation who may be affected by the work should be made aware of the hazards posed by each of the contamination ground investigation sites, and the measures required to reduce associated risks. This awareness is necessary whether the involvement concerns site visits, site reconnaissance or ground investigation.

7.11 Training should cover legal responsibilities, types of hazards and special measures to be taken on potentially contaminated sites. Issues which may need to be covered include risks of diseases (e.g. tetanus, anthrax and Weils disease) associated with certain landfills and contaminated ground, and risks from certain work (e.g. welding/burning) near areas with potential sources of explosive or flammable gases. Training will be necessary in the use of specialist equipment, such as gas monitoring equipment and breathing apparatus. Specialist first aid training may be appropriate.

7.12 The responsibility for health and safety during the site investigation work should be entrusted to individuals with appropriate experience, training and qualification.

Safety Plan

7.13 The need for safety equipment and facilities should be evaluated, and the conclusions of this evaluation should be formulated by the contractor in a Project Safety Plan before the start of ground investigation field work. The plan should describe site safety measures and emergency procedures, including those unrelated to ground contamination, and will apply to the whole of the land on which ground investigation is being undertaken. The Safety Plan should also provide details of emergency procedures which should include emergency telephone numbers and the location of the nearest hospital casualty department. Health and Safety measures associated with sample handling testing should also be considered in the Safety Plan.

7.14 In view of the additional hazards that may arise during investigation of the potentially contaminated sites, the Safety Plan should address each site individually, pointing out the required procedures specific to those sites and the recommendations resulting from the COSHH assessment. Individuals responsible for health and safety (in the Design Organisation and with the Contractor) should ensure that all their personnel involved with ground investigation on those sites have received copies of the Safety Plan and are aware of the procedures described therein.

7.15 For a potentially contaminated site identified as low risk, the Safety Plan may identify very few additional provisions and restrictions (eg provision of washing facilities, restrictions on smoking or consumption of food and drink). For a high risk site, the Safety Plan would usually identify the need for many more restrictions which may include a site induction course for all site personnel, enhanced first aid facilities, special clothing, monitoring, wheel washing and a decontamination unit.

8. DESIGN OF CONTAMINATION GROUND INVESTIGATIONS

General Considerations

8.1 The contamination ground investigation (CGI) should be planned in the light of knowledge of site conditions gained during the desk study and of the probable disposition of earthworks, structures, and effects on adjoining land and natural resources.

8.2 CGIs for highway schemes usually comprise the examination of ground conditions at several, or many, specific sites within the study area. The sites will be mainly on-line and may vary in hazard classification between high risk and low risk sites. The investigation of each site must be considered separately in recognition of the particular characteristics of the site, and its potential impact on the proposed scheme.

8.3 The CGI should also be planned to provide sufficient information to tenderers for the main scheme construction contract to assess and price the works, including costs of identifying and dealing with contaminated soil and waste, protective measures and monitoring.

8.4 There are important constraints on a flexible, site-specific approach to the design of the CGI for a highway scheme. These constraints principally concern the following:

(i) The arrangement of access for ground investigation equipment on to land owned by others;

(ii) The capabilities of a single contractor to carry out a combined ground investigation and CGI for the whole scheme in a single phase of investigation.

8.5 The CGI is usually conducted in parallel with the geotechnical investigation. The possible effects of contamination on the interpretation of standard geotechnical field and laboratory tests should be considered carefully when evaluating the physical characteristics of the ground. Particular problems arise when the source of contamination is an "unnatural" material such as made ground, industrial waste, domestic refuse etc., where chemical composition, presence of biodegradable matter and heterogeneity can all invalidate conventional interpretations of strength and compressibility from field and laboratory testing. In such circumstances, a detailed description of the ground, and reference to case histories with similar materials is particularly important in the evaluation of physical properties. Field loading tests, such as trial embankments and skip loading tests, may also be valuable.

Phasing of the Investigation

8.6 The phasing of the CGI will be influenced by the risk assessment of the site (Chapter 6). Where particular hazards or uncertainties are identified for certain sites during the desk study, it may be advisable to carry out a preliminary CGI in advance of the main ground investigation for the scheme. This would normally only apply to high risk sites. The objectives of the preliminary investigation would be to provide sufficient information to allow the main investigation to be adequately planned and might involve specialist contractors or techniques (eg geophysics).

8.7 For sites classified as moderate or low risk, a preliminary CGI would not normally be required, although for moderate risk sites, consideration should be given to carrying out sampling (from trial pits) and testing for contamination in advance of geotechnical boreholes.

8.8 CGIs may involve a period of groundwater or soil gas monitoring after completion of the site works. This would usually extend for several weeks, but a longer period of monitoring may be required if seasonal effects are likely to be significant.

Investigation Techniques

8.9 Investigation techniques for potentially contaminated sites generally utilise the same, or similar, equipment to that used for conventional ground investigations although sampling protocols may be different. The methods adopted are either intrusive (usually involving the excavation of boreholes or trial pits) or non-intrusive (such as geophysical techniques). Certain types of equipment are particularly suited, or have been specifically designed, for contaminated land. Techniques which minimise cross contamination are

essential. Techniques which minimise arisings at the surface have significant advantages in reducing risks.

8.10 Investigation techniques that may be used on potentially contaminated sites include the following:

(i) Geophysical techniques;

(ii) Trial pits;

(iii) Cable percussion boring;

(iv) Rotary hollow stem boring;

(v) Percussion sampling;

(vi) Cone penetration sampling and testing;

(vii) Soil gas surveys;

(viii) In-situ monitoring for soil gases and groundwater quality.

The application of these various techniques is discussed in the following sections.

Geophysical Techniques

8.11 Geophysical techniques are indirect methods of investigation which use the properties of subsurface materials such as density and electrical resistivity to indicate changes in ground conditions. The techniques are particularly useful when there are contrasts in physical properties and may be used cost effectively to locate anomalies in an area for further investigation by drilling or excavation. The geophysical methods may assist in determining the limits of areas possibly containing hazardous materials (such as the edges of landfills) and hence reduce the extent of intrusive ground investigation required. They do not, however, remove the requirement for intrusive ground investigation. Like other forms of site investigation, these methods require a prior desk study which will indicate which types of geophysical technique might be suitable. Performance of the work and interpretation of the results should be undertaken by suitably qualified and experienced specialists.

8.12 Ground penetrating radar is a technique which makes use of electromagnetic pulses which are transmitted into the ground, with the return time giving an indication of ground conditions. It is a method useful for detecting buried tanks at shallow depth, but performs poorly in clay soils and water saturated soils. The equipment is drawn across the surface of the ground on a grid pattern and is therefore only suitable where the surface of the site is relatively even. The results from ground radar are often difficult to interpret.

8.13 The electrical resistivity of the ground can be measured using an array of electrode spikes which are pushed or driven into the ground. The measurements can be used to differentiate between saturated and unsaturated soils, and interpretation may provide profiles and depths of fill. It is a method which is sensitive to local variations, but is not suited to areas of hardstanding.

8.14 Magnetic surveys, carried out using portable equipment comprising a magnetometer and sensors mounted on staffs, are suitable to detect buried metallic objects. These surveys are affected by temporal variations in the magnetic field and by sources of non-ionising radiation.

8.15 Conductivity surveys are undertaken by traversing the site with hand held equipment. The conductivity measurements can be used to interpret variations in groundwater quality and the presence of buried metallic objects.

8.16 Self polarisation involves the detection of electrochemical gradients using electrodes placed in the ground. Different concentrations of dissolved ions in groundwater can be detected and the techniques can be suitable to determine the edges of contaminated sites that have boundaries defined by contrasting groundwater quality.

8.17 Seismic refraction surveys have been used for many years as a method of shallow geological survey and involve methods derived from seismic reflection surveys used extensively in the petroleum industry. Seismic refraction surveys may be used to estimate the thickness and depth of lithological units with differing densities. This technique is also suitable for establishing the depth of the groundwater table or vertical boundaries such as the edge of old backfilled quarry walls. The arrival of a shockwave, usually provided by a hammer blow on a steel plate at the surface, is monitored by an array of geophones. The technique is non-intrusive and may be carried out on many different types of sites.

8.18 Infra-red thermographic surveys and infra-red photography are techniques which can be used to detect contaminated ground, particularly landfill sites. Thermographic surveys detect temperature differences in the ground surface which may be due to the exothermic reactions in landfill sites or underground heating in coal rich spoil tips. The surveys can be undertaken by helicopter or locally by crane mounted

hoists. Helicopter surveys are particularly useful in examining several or many sites along a proposed highway alignment and can be a valuable and cost effective means of screening sites during a preliminary survey. The surveys should be carried out at daybreak in calm weather conditions, and are not suitable if the surface is covered by snow or affected by a heavy frost. Infra-red photography detects differences in reflected energy and can highlight distressed vegetation which may result from contaminated ground or landfill gases (but may also be caused by natural effects such as waterlogging). Infra-red photography may be carried out during the daytime.

Trial Pits

8.19 The excavation of trial pits by mechanical excavator is probably the most widely used technique for sampling potentially contaminated ground. The advantages of the method are its applicability to a wide range of ground conditions, opportunity for close visual examination of the soils, and the speed with which the work can be carried out, which usually results in it being a cost effective method of investigation. The method is not suitable where there is a high groundwater table owing to instability. The practical depth of the technique is about 4.5m.

8.20 When excavating trial pits on contaminated land, particular care must be taken to ensure that surrounding areas are not affected by the excavated spoil, and that the reinstatement of the trial pits does not leave contaminants exposed. For health and safety reasons, trial pits should not be entered. Hence, sampling should be carried out using long handled tools or from the bucket of the excavator. Volatile contaminants are readily lost from material to be sampled unless great care is exercised.

Cable Percussion Boring

8.21 Conventional percussion boring techniques may be used to collect soil samples and to enable the installation of groundwater monitoring wells and gas standpipes. Soil samples recovered from cable percussion boreholes will only be suitable for chemical testing if they have been taken from samplers (such as SPT and U100) enabling the depth of the sampling point to be determined. Disturbed soil samples taken from the shell, and samples of standing water taken from the boreholes will not generally be suitable for chemical testing due to the potential for cross contamination.

Hollow Stem Auger Boring

8.22 Hollow stem auger boring is an acceptable technique for sampling contaminated soils, and since it provides a fully cased hole, can avoid some of the potential cross contamination problems of conventional percussion boring. Soil samples for laboratory testing should only be taken from appropriately designed open drive samplers or core barrels installed within the hollow stem. This method of drilling has been found to be successful on some landfill sites and is suitable for the installation of groundwater monitoring wells and gas standpipes.

Percussion Sampling

8.23 Lightweight equipment comprising "flow-through" or "window" casings which are driven into the ground using a portable petrol driven hammer or a small rig with a drop hammer are available for carrying out site investigations up to about 8m depth, depending on the ground conditions. This equipment is suitable for sites with confined access or where minimal disturbance to the land is necessary. It is not suitable for dense gravels or cohesionless soils below the water table. It is also less cost effective in areas of hardstanding which require coring.

Cone Penetration Sampling and Testing

8.24 Static probing electric cone penetrometer equipment mounted within purpose built trucks or on all-terrain vehicles may be used to obtain good quality groundwater samples, and to obtain soil and soil gas samples. This equipment may also be used to measure the pH, redox potential and temperature of groundwater in-situ (using a chemical sounding probe) and to carry out geophysical tests with depth, such as conductivity surveys (using a conductivity probe, paragraph 8.15). This method of investigation can be more expensive than conventional techniques but offers the following advantages:

(i) no soil or groundwater drilling products;

(ii) no contaminated spoil brought to the surface;

(iii) high quality samples;

(iv) does not chemically disturb the groundwater system;

(v) minimal human contact or exposure to contaminated materials.

Soil Gas Surveys

8.25 Soil gas surveys are particularly useful to delineate the extent of hydrocarbon or solvent spillages, or to detect landfill gases. Contours of equal apparent concentration can be used to infer migration of contaminants or to identify appropriate locations for gas abstraction wells.

A quick and cheap technique of assessing the presence and concentration of soil gases involves driving a hollow metal probe into the ground to which may be connected a gas detector or gas sampling equipment. Lightweight percussion rigs (8.23) may also be used to install permanent or semi-permanent sampling points comprising slotted or perforated plastic casings.

8.26 Simple surveys can also be undertaken by driving a metal spike into the ground to form a hole and then removing the spike and measuring concentration of gases (typically methane, carbon dioxide and oxygen) in the hole using portable instruments. Although very quick and cheap, this technique has considerable limitations as a general site investigation method. There is the possibility of air ingress into the hole and the probes are limited not only by depth (about 1m) but also have a very limited sphere of influence in low permeability soils. Consequently, although the technique can confirm the presence of particular gases, a negative result from the spiking survey does not demonstrate absence of that particular gas.

Insitu Monitoring for Soil Gases and Groundwater Quality

8.27 The monitoring of groundwater quality, as well as groundwater levels is a routine part of a CGI. Insitu soil gas monitoring is also frequently required. The drilling method chosen for the CGI must be suitable for the installation of properly constructed gas and groundwater monitoring wells.

8.28 The construction of wells should be such that groundwater samples can be obtained from discrete depths. A seal should be constructed at the surface of the well to avoid infiltration of surface water.

8.29 Groundwater samples may also be obtained using pushed or driven piezometers.

8.30 Gas sampling wells are usually constructed as standpipes using at least 50mm ID perforated casing in gravel surround, sealed at the surface. The gas standpipe should extend the full depth of the potentially gassing ground, or to the depth of the groundwater table, whichever is less. Gas standpipes may also be used as groundwater monitoring wells.

8.31 The construction of gas monitoring wells with twin valves and an inner tube suspended just above the bottom of the standpipe (or standing water level - whichever is higher) is recommended, as shown on Figure 8/1. This enables separate gas concentration readings to be taken as follows:

(i) top of standpipe
(ii) bottom of standpipe
(iii) concentration after circulation of the gas.

The level of the suspended tube does not just measure gas concentrations at that level. Soil gases can be lighter and heavier than air and will accumulate at the top and base of the standpipe.

8.32 Readings should be undertaken over a period of time (depending on the conditions) and taking into account of factors such as atmospheric pressure and emission rate. Advice on gas monitoring may be obtained from Waste Management Paper No 27 "Landfill Gas" (16) and the CIRIA report "The Measurement of Methane and Other Gases from the Ground" (22).

Number and Spacing of Exploratory Holes

8.33 The location of exploratory holes for geotechnical investigations will generally be dictated by the requirements of the highway works, with major structures and areas of cut requiring the most intensive investigation. In planning the contamination ground investigation, the desk study findings should be taken into account, identifying areas where contamination is most likely to occur and where such contamination is likely to affect the proposed works.

8.34 For large areas of potentially contaminated land, gross or critical contamination may be confined to specific areas ('hot-spots'). In such situations, a regular pattern of exploratory holes may be required to locate 'hot-spots'. Research has shown that a stratified systematic unaligned pattern is likely to be the optimum sampling plan (23). The spacing of the grid should take into consideration the proposed earthworks, the assumed severity and extent of potential contamination, and the confidence level required. The extent of more hazardous contaminants will need to be known with greater confidence than less hazardous ones. Sampling strategies have been the subject of research sponsored by the Department of the Environment, and further information on sampling and sampling plans is given in the research report (27).

Depth of Exploratory Holes and Sampling Frequency

8.35 The approximate depth of potentially contaminated ground should be assessed based on the desk study and proposed highway works prior to the investigation. This will enable the development of a sampling strategy identifying the frequency and general location of samples and exploratory holes along the highway route. The type and number of soil samples taken should be representative of all the materials encountered and be sufficient to allow the required chemical analysis.

8.36 The technical staff responsible for the scheduling of chemical analyses should be involved during the planning and fieldwork stages of the investigation. The personnel on site need to understand the sampling strategy to ensure truly representative samples are taken.

8.37 The frequency of soil and water samples removed from each sample location will depend on the investigation techniques selected. In general, soil samples suitable for chemical testing should be taken from each stratum encountered at each exploration point, and at a vertical spacing of not more than 1 metre throughout the depth of the exploratory hole.

8.38 As a guide the sampling strategy could involve the following frequency of sampling.

a) During the development of a trial pit the first sample is taken at the surface or from the near-surface stratum (<0.15m). Samples of each further stratum or samples every 1m (whichever is the greater number of samples) are then taken. This will normally involve the collection of 4 or 5 samples.

b) During the development of boreholes, the first sample is taken at 0.15m depth then at 1m intervals to the full depth of the potentially contaminated ground. Additional samples of any suspicious material encountered during drilling should also be taken.

8.39 Although some types of contamination can be recognised by their colour or texture by trained personnel, it is not always the case and should not be relied upon as part of a sampling strategy. Groundwater should be sampled whenever encountered. Where more than one groundwater table is found, each should be sampled separately.

Methods of Sampling

8.40 Results of chemical analysis depend strongly on the method of sampling and in-situ treatment of samples. Other factors which may affect the results include the type and cleanliness of the sampling equipment and sample containers and the time between sampling and analysis. Sample containers, likewise, should be clean, non-reactive and non adsorbing. Guidance on sampling, preserving and handling of water samples is given in BS 6068 Part 6 (24).

8.41 Water samples recovered from boreholes and trial pits during their excavation can be taken using a number of sampling devices such as balers or pumps. However, the potential for cross contamination of these samples by the exploration process should be recognised.

8.42 Groundwater samples can best be obtained from standpipes sealed at ground level or from groundwater sampling wells with discrete sealed off sections. Controlled sampling protocols are required to obtain representative samples. These protocols involve purging, in-situ analysis, preservation and filtration for certain determinands and the use of fixing agents and various different sample containers for storage, depending on the requirements of subsequent chemical analysis.

8.43 Strict sampling protocols should also address the conditions of sample transport and storage, including temperature and time. To prevent chemical alteration of target compounds, samples should be kept cool until tested. Marking of samples and chain of custody forms are essential to avoid errors during transport or storage. For certain contaminants, tests must be started within 24 hours.

Laboratory Testing

8.44 It is important that the chemical analysis techniques are fully defined in specifications prior to the investigation fieldwork. There are direct links between the analysis method (including sample preparation and extraction) and the results obtained. The test method must be fully compatible with the method to be used for assessing the results. Detection limits must be specified which are compatible with the requirements of the subsequent interpretation.

8.45 The choice of chemical analysis suites should be primarily based on the history of the various sites under investigation and the proposed construction works.

8.46 Apart from tests for chemicals generally associated with specific site use, there are a number of qualitative and quantitative tests that are necessary in classifying contaminative types and the behaviour of particular contaminants in the existing matrix (soil or water). It is essential to test the pH, especially when metals might be present. Other useful tests include electrical conductivity and leaching tests. Screening tests such as solvent extraction are relatively cheap and useful but must be combined with more detailed analysis to determine concentrations of particular contaminants.

8.47 Quality control is important at all stages of the field and laboratory work to ensure reliable analysis results. It is good practice to require specified analyses to be undertaken on additional samples (particularly water samples) prepared both on site and in the laboratory to identify any errors in the sampling and analysis programme. Additional samples include replicate, spiked, blank and reagent samples which are generally a routine part of the laboratory quality control programme.

8.48 Third party accreditation should be taken into account by the Design Organisation in assessing the suitability of analytical laboratories. Evidence of quality control is also offered by involvement in proficiency testing schemes, in which a laboratory's performance of various tests is monitored against other laboratories conducting similar tests.

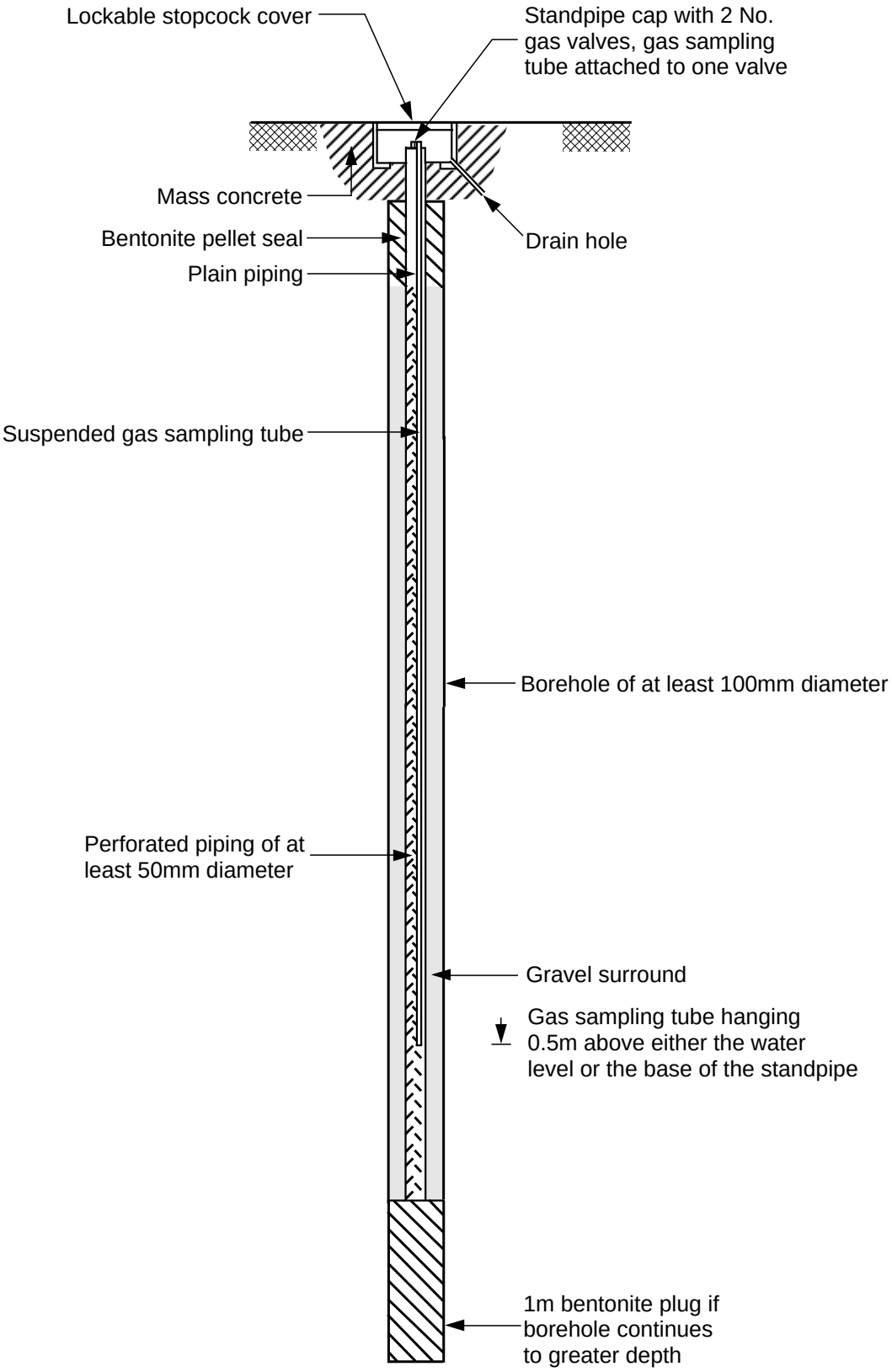

Figure 8/1. Typical details of gas monitoring standpipe

9. PERSONNEL

General

9.1 Personnel supervising site investigation on potentially contaminated sites should have relevant previous experience, and all personnel involved should be appropriately qualified and trained, in order to minimise the associated risks.

Direction and Planning

9.2 The investigation of potentially contaminated sites on highway schemes requires additional skills to those used in the design of the geotechnical investigations for the scheme. The planning of the contamination ground investigation should be undertaken by a suitably competent person who should be an environmental specialist designated by the Design Organisation. This person should report to the Design Organisation's Geotechnical Engineer.

Site Work

9.3 The Design Organisation will be responsible for the design, direction, control, interpretation and overall adequacy of the investigation, and will therefore have to provide the appropriate level of site supervision to fulfil that responsibility.

9.4 The Contractor should nominate an experienced and suitably qualified competent person, referred to here as the Environmental Specialist, to undertake specialist work during the conduct of the site works. This person(s) must have suitable experience to be able to recognise hazards by sight, smell or in-situ testing, and to incorporate necessary changes to working procedures. The Environmental Specialist should be able to advise on selecting suitable sampling points and to advise on health and safety matters on site. The Environmental Specialist's duties for the contractor should also include:

(i) Collecting representative samples from the sampling points, including preservation of the samples as required;
(ii) Taking on site measurements;
(iii) Ensuring that information from trial pits and boreholes is recorded properly;
(iv) Ensuring that quality control procedures are adhered to in handling and transport of samples;

9.5 The Environmental Specialist must ensure that all site operatives are made fully aware of hazards and special procedures to be followed. Operatives involved with drilling and sampling must be trained in the particular methods required. Drillers should preferably be accredited by the British Drilling Association or recognised equivalent in the European Economic Area as "Ground Investigation Drillers" with appropriate training relevant to work on contaminated land. All operatives should be trained to recognise routine hazards and to administer basic first aid.

Laboratory Work

9.6 Personnel involved with laboratory work on samples of soil, water and gas should have experience of such work and be appropriately qualified and trained. This is necessary to ensure the general accuracy and reliability of the results.

Interpretation

9.7 Personnel interpreting the results of contamination ground investigations should have appropriate qualifications, training and experience in the assessment of contamination and should preferably also have been involved in the monitoring of the site works and in the specification of the contamination tests.

10. LEGISLATION

Introduction

10.1 This chapter highlights legislation addressing ground contamination and legal issues which may affect the design or implementation of ground investigations. The principal aspect concerns the potential of CGIs to have an adverse impact on the environment and the duties of parties involved to avoid or minimise this impact. However, there are other issues to be addressed, such as liabilities affecting landowners.

Present Legislation

10.2 Present legislation affecting contaminated land consists of statutes, the most significant of which are noted below, and common law, including a large number of cases which address issues such as nuisance, negligence and trespass. The law in these areas continues to develop.

10.3 The Environmental Protection Act 1990 (EPA) is the most wide ranging statute addressing the environment. It introduces a number of measures to control pollution and deterioration of the environment. Although the EPA was enacted on 1 January 1991, many of its sections have yet to be put in force. Thus certain aspects of environmental control may still be governed by previous Acts, such as the Control of Pollution Act (COPA) 1974. The sections of the EPA with relevance to site investigations on contaminated land include sections 33 (Prohibition of unauthorised disposal of waste), 34 (Duty of Care), 35 (Waste Management Licensing), 79-82 (Statutory Nuisance). In Scotland, statutory nuisance is governed by the Public Health (Scotland) Act 1897 as amended by Section 83 of the EPA. In Northern Ireland, the Pollution Control and Local Government (Northern Ireland) Order 1978 applies.

10.4 The Water Resources Act 1991 largely supersedes the Water Act 1989 which consolidated water legislation and established the National Rivers Authority (NRA) for implementing water pollution controls in England and Wales. Sections 85 and 161 of the Water Resources Act concerning pollution of controlled waters are particularly relevant to contaminated land. In Scotland, legislation covering water control consists primarily of COPA and the Water (Scotland) Act 1980, amended by the Water Act 1989. In Northern Ireland, the Water Act (Northern Ireland) 1972 legislates on water control.

10.5 Other statutes of relevance to site investigation on contaminated land include the Health and Safety at Work Act 1974, (which is discussed in Chapter 7) and the Control of Pollution Act 1974 (which concerns waste disposal and also addresses pollution of waters).

Pollution

10.6 Under Clause 29 of the ICE Conditions of Contract for Ground Investigation as amended by the appropriate Overseeing Organisations, the Contractor is under an obligation to "..... take all reasonable precautions:-

a) in connection with any rivers, streams, waterways, drains, water courses, lakes and the like to prevent:-

   i silting;
   ii erosion of their beds or banks;
   iii pollution of the water so as to affect adversely the quality or appearance thereof or cause injury or death to animal and plant life.

b) in connection with underground water resources (including percolating water) to prevent:-

   i any interference with the supply to or abstraction from such sources;
   ii pollution of the water so as to affect adversely the quality thereof."

10.7 The above covers the Contractor's obligations in carrying out the fieldwork element of the investigation. However, in undertaking the site operations the "status quo" of the contaminated land could be disturbed, with the possibility of both short term and long term environmental risks. The magnitude of these risks will be related to the nature of the contaminants present on the site being investigated, and also the proximity of any watercourses and/or habitation.

10.8 Ground investigations may disturb the stability of contaminated sites with consequential pollution. Thus, the undertaking of an investigation on a former landfill site which may result in the puncturing of an "engineered cap" needs to be given careful consideration. The presence of artesian groundwater will greatly exacerbate the problem.

Duty of Care

10.9 Section 34 of the Environmental Protection Act imposes a Duty of Care on any persons who produce, carry, keep or dispose of controlled waste to take all measures reasonable in the circumstances to prevent escape of the waste from their control or that of any other person and ensure that waste is only transferred to an authorised person and is accompanied by a written description of the waste. Controlled waste, as defined in Section 75 of the Act, includes spoil produced during ground investigations which requires disposal. Breach of the Duty of Care is a criminal offence.

10.10 Waste disposal licensing is currently governed by the Control of Pollution Act 1974 (COPA), the Control of Pollution (Amendment) Act 1989 and the Environmental Protection Act 1990 (EPA). Whilst much of the COPA has been re-enacted in EPA, the Special Waste Regulations SI 1980 No 1709 made under COPA are still extant and relevant to contaminated ground investigation. These define special waste and cover the preparation of consignment notes by the producer of the special waste. The Control of Pollution (Amendment) Act 1989 covers the requirements of carriers of controlled waste to be registered. Section 35 of the EPA has now been implemented by means of The Waste Management Regulations SI 1994 No 1056, covering the licensing requirements for the depositing, treating and storing of controlled waste. The Collection and Disposal of Waste Regulations 1988 provide details on when a waste disposal licence is required.

Nuisance

10.11 Odours or migrating landfill gas from contaminated sites may cause nuisance. Under the EPA (Sections 79 and 82), health and safety legislation and common law, the site owners have a responsibility to ensure that the site does not cause a nuisance.

Access

10.12 For the majority of non-highway ground investigations the promoter of the investigation is the owner of the site, and hence there are no problems with access. However, for highway schemes, the ground investigations generally occur early in the scheme design process (usually before the publication of the Scheme Line Orders). As a consequence of this, the investigation is carried out on land not in the ownership of the Overseeing Organisation.

10.13 When undertaking ground investigations, the Overseeing Organisation endeavours to gain access to the Third Party's land by agreement. This agreement is normally in the form of a Wayleave Agreement, and under the terms of the agreement the Overseeing Organisation undertakes to pay compensation for damage to the land and disturbance to the landowner and/or occupier, the compensation payable being determined on the same basis as if entry had been taken under Section 289 of the Highways Act 1980 or in Scotland, Section 140 of the Roads (Scotland) Act 1984. However, if agreement is not given, the Overseeing Organisation can then resort to its powers to "search and bore" under Section 289 of the Highways Act 1980 or Section 140 of the Roads (Scotland) Act 1984. The use of these powers may influence the choice of investigatory fieldwork technique and due consideration should be given to this fact. These Acts also enables apparatus (i.e. monitoring equipment) to be placed and left on the land. In Northern Ireland, Section 119 of the Roads (Northern Ireland) Order 1993 covers these matters.

11. REPORT FORMAT

11.1 Both a Factual Report and an Interpretative Report should be prepared at the conclusion of the CGI. The Factual Report is prepared by the Contractor who has undertaken the investigation. The Interpretative Report is prepared either by the Contractor or by the Design Organisation who may be assisted by specialists.

Requirements for Factual Reports

11.2 This report should include all factual information concerning the location, details of the method of investigation and sampling, and results of the investigation. Laboratory test results should be presented with full details of the sample preparation procedures and analysis techniques, limitations of the methods used (such as accuracy, limit of detection), and details of any controls (blanks and spiked samples). The report should also include plans and sections showing the location of all exploratory holes, the depth at which samples were taken, confirmed geological strata and groundwater levels. Depending upon the size of highway project and number and type of potentially contaminated sites investigated, the Factual Report on the CGI could be a section within the Factual Report for the ground investigation. For larger projects it is preferable for a separate volume to be prepared for the CGI containing all the information listed above. A suggested contents list for the Factual Report is given in Appendix C.

Requirements for Interpretative Reports

11.3 The Interpretative Report should discuss the potential impacts which any contamination may have on the highway works (and vice versa). In addition, it should provide the Design Organisation with the necessary information for the determination of the requirements for dealing with Class U2 Unacceptable Material when preparing the main construction contract.

11.4 The Interpretative Report should address any changes that may be brought about by the presence of contamination to the proposed works, and should include an appraisal of any aspect of the works affected by contamination. Where there are significant effects, mitigation measures should be recommended. These may include protection against aggressive or toxic chemicals and gas protection measures. A suggested contents list for the Interpretative Report is given in Appendix C.

11.5 The Interpretative Report should be prepared by an appropriately qualified specialist. The interpretation of chemical analysis results should be undertaken by personnel understanding the limitations of the assessment techniques and appreciating potential sources of error in the derivation of data, which will limit the scope of interpretation. Personnel carrying out the interpretation should also be familiar with the proposed highway works, be able to identify the impact of contamination on the works (and vice-versa) and be able to propose appropriate remedial techniques.

11.6 The assessment of contamination should follow a risk assessment approach. This should consider the contamination hazards identified in the site investigation, susceptible human, natural and material targets and feasible pathways for contact between the two.

12. REFERENCES AND BIBLIOGRAPHY

Design Manual for Roads and Bridges (DMRB)

1. HA 34. Ground Investigation Procedure. (DMRB 4.1.3).

2. HD 22. Ground Investigation and Earthworks - Procedure for Geotechnical Certification. (DMRB 4.1.2).

3. Volume 11. Environmental Assessment. (DMRB 11).

Manual of Contract Documents for Highway Works (MCHW).

4. Specification for Highway Works (MCHW1)

5 Interdepartmental Committee on the Redevelopment of Contaminated Land (1987). Guidance on the Assessment and Redevelopment of Contaminated Land. Guidance Note 59/83, 2nd Edition.

6. Interdepartmental Committee on the Redevelopment of Contaminated Land (1990). Notes on the Development and After-Use of Landfill Sites. Guidance Note 17/78, 8th Edition.

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18. Dumbleton M.J. (1984). Air Photographs for Investigating Natural Changes, Past Uses and Present Condition of Engineering Sites. DoE : Transport and Road Research Laboratory Report LR 1085.

19. Steeds, J.E., Shepherd, E. & Barry, D.L. (1993). A Guide to Safe Working Practices for Contaminated Sites. CIRIA Funders Report/CP/9. July 1993.

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23. Ferguson, C (1992), Statistical Basis for Spatial Sampling of Contaminated Land. Ground Engineering, 25 (5), June 1992, pp 34-38.

24. British Standards Institution (1986): Water Quality, BS6068 Part 6. Sampling.

25. Department of the Environment (1994). A Framework for Assessing the Impact of Contaminated Land on Groundwater and Surface Water. CLR Report No. 1, volumes 1 and 2.

26. Department of the Environment (1994). Documentary Research on Industrial Sites. CLR Report No. 3.

27. Department of the Environment (1994). Sampling Strategies for Contaminated Land. CLR Report No. 4.

28. Institution of Civil Engineers (1994). Design guide on contaminated land. Thomas Telford, London.

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British Standards Institution (1988). Code of Practice for Selection, Installation, Use and Maintenance of Apparatus for the Detection and Measurement of Combustible Gases (other than for mining applications or explosives processing and manufacturing), BS. 6959.

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Department of the Environment (1982). Special Waste. Waste Management Paper No 23. HMSO, London.

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Site Investigation Steering Group (1993). Site Investigation in Construction Part 3: Specification for Ground Investigation. Thomas Telford, London.

Weltman, A.J. & Head, J.M., (1983). Site Investigation Manual. CIRIA Special Publication 25, 1983.

Wilson, D.C. and Stevens, C. (1988). Problems Arising from the Redevelopment of Gas Works and Similar Sites. 2nd Edition, HMSO, London.

13. ENQUIRIES

All technical enquiries or comments on this Advice Note should be sent in writing as appropriate to:

Head of Division
Road Engineering and Environmental Division
St Christopher House
Southwark Street
London SE1 OTE

N S ORGAN
Head of Division

The Deputy Chief Engineer
The Scottish Office Industry Department
Roads Directorate
New St Andrew's House
Edinburgh EH1 3TA

N B MACKENZIE
Deputy Chief Engineer

Head of Roads Engineering (Construction) Division
Welsh Office
Y Swyddfa Gymreig
Government Buildings
Ty Glas Road
Llanishen
Cardiff CF4 5PL

B H HAWKER
Head of Roads Engineering
(Construction) Division

Assistant Chief Engineer (Works)
Department of the Environment for
Northern Ireland
Roads Service Headquarters
Clarence Court
10-18 Adelaide Street
Belfast BT2 8GB

D O'HAGAN
Assistant Chief Engineer (Works)

POTENTIAL CONTAMINANTS RELATED TO USES OF LAND

The table below has been prepared as a guide to the groups of potential contaminants that may be found associated with certain land uses. The list is not intended to be exhaustive, nor to present a definitive guide to the potential contamination at the site. Investigation into all potential past site uses would be required before a more comprehensive picture of potential contamination can be achieved. It should be appreciated that more than one potentially contaminative use may have been operating at any particular site.

Site Use	Potential Contaminants		Notes
Asbestos works	Inorganic:	hardened asbestos cement slurry loose/sheet asbestos asbestos sludge from settlement tanks	The manufacturing process is the main source of asbestos fibres.
	NB Major hazard is associated with fibres. The 3 main forms are:		
	(i)	chrysotile (white asbestos)	
	(ii)	crocidolite (blue asbestos)	
	(iii)	amosite (brown asbestos)	
Brickworks	Disused Brickworks often subsequently used for landfilling operations. See landfill.		
Chemical Works	Inorganic:	Chlorine Hydroxides Carbonates Sulphates Cr, Hg, Zn, As Asbestos	Types of works: Chlor-alkali industry.
	Organic:	Coal tar derivatives e.g. Tar acids - e.g. phenols, cresols and xylenols Tar bases e.g. Pyridine PAHs Benzene, Toluene, Ethyl benzene, Xylene Volatile aromatic and aliphatic hydrocarbons Mercaptans Chlorinated hydrocarbons	Inorganic pigment manufacture. Various chemicals and feedstocks
Docklands (including filled dock basins)	Inorganic:	Sn, Cu, Pb, As, Hg, Ni, Mn, Cr, Cd, Zn, Mg Sulphates, sulphides Chlorides Cyanides Asbestos	Fill material. Dock basins sediments. On-site activities such as work/paint shops, shipmaking, breaking, repair.
	Organic:	Mineral oils Coal tar derivatives (See Chemical Works) PCBs Organotins Chlorinated and non chlorinated solvents	
	Biological:	Possible hazard of leptospirosis or Weil's Disease	
	Gases:	Methane, hydrogen, sulphide	

Site Use	Potential Contaminants		Notes
Garages	Inorganic:	Cr, Zn, Pb, Hg, Cd, As Acids	Site activities such as spray painting, engine repair and welding, fuel storage. Ground contaminated by fuels may be combustible.
	Organic:	Organometals e.g. alkyl lead Fuel oils and hydrocarbons Mineral oils Organic solvents	
Gasworks	Inorganic:	Fe, Ti, Mn, As, Al,Cr, Cu, Pb, V, Zn, Cd, Mo, Se, Ni and Hg Ammonia and ammonium salts Sulphur, sulphates, sulphides including thiosulphate Iron (Ferric) oxides Cyanides, including thiocyanate and "blue billy" Compounds of Ca, Na, K, Acids e.g. H_2SO_4, HCl Chlorides	Coal/coke/oil. Gas production process. Sites often contain buried tanks or wells.
	Organic:	Coal tar derivatives (See Chemical Works) Coal and Coke residues Water Treatment and anti-corrosion chemicals	Cooling water.
Iron and Steel Works	Inorganic:	Zn, Pb, Cu, Cr, N, Al, As, Sn, B, P Mg. Mn Sulphates/Sulphides Chlorides Ammonia Cyanides Acids	Coke manufacture and subsequent iron and steel manufacture. Asbestos may be present in demolition rubble
	Organic:	Coal tar derivatives (See Chemical Works)	
Landfill Sites (and Waste Disposal)	Inorganic:	Na, K, Mg, Ca, Cr, Mn, Fe, Ni, Co, Zn, Cd, Pb, Hg Nitrate, Nitrite Phosphate Sulphate	Will depend greatly on which materials have been filled e.g. domestic and/or industrial.
	Organic:	Coal tar derivatives (See Chemical Works) Pesticides (See Timber Products)	After 1976 all sites should have been licensed, as required by COPA 1974.
	Gases:	Methane and carbon dioxide Hydrogen sulphide Carbon monoxide	Waste Regulation Authorities issue the licences.

Site Use	Potential Contaminants		Notes
Metal Smelting and Refining	Inorganic:	Pb, Zn, Cu, Cr, Ni, Al, As, Sn, B, P, S, Mg, Mn Sulphates/Sulphides Chlorides Cyanides Ammonia Acids	Coke manufacture and subsequent metal/alloy production.
	Organic:	Coal tar derivatives Mineral oils Organic solvents	
Metal Treatment and Finishing	Inorganic:	Pb, Cr, Cu, Zn, Ni, Cd, Fe, Sn Chromates Sulphate/Sulphides Cyanide Chloride compounds Alkalis e.g sodium hydroxide.. Acids e.g. sulphuric and nitric Phosphate	Casting, pickling galvanizing and coating processes.
	Organic:	Mineral oils/grease Chlorinated organic solvents	
	Radiological:	Thorium, radium also uranium isotopes.	
Mineral and Metal Extraction (including coal)	Inorganic:	Metal ore residues and slags Dust Acidic run-off Heavy metals (Pb, Zn, Cu, Sn, As, Cd) Sulphates, Sulphides	Raw material and residue storage.
	Organic:	Coal tar derivatives (See Chemical Works)	
	Gases	Methane Carbon Monoxide Carbon dioxide Hydrogen sulphide	
Munitions Manufacture	Inorganic:	Heavy metals Sulphate/sulphides Acid e.g. nitric and sulphuric	Pyrotechnics, various explosives and specialist alloys.
	Organic:	Organic solvents Nitro compounds	
	Radiological:	Possible wide range present e.g. uranium and thorium isotopes	

Site Use	Potential Contaminants		Notes
Oil Storage	Inorganic:	Ammonia Sulphur compounds As, V, Mn, Zn Asbestos	Residues, leakage.
	Organic:	Coal tar derivatives (See Chemical Works) Organometals	
Paints Manufacture	Inorganic:	Pb, As, Cr, Hg, Cd, Cu, Co, Sn, Cyanides Asbestos	Manufacturing process involving pigments, binders, oils and solvents.
	Organic:	Organic solvents halogenated hydrocarbons pesticides detergents	
Petroleum and Oil Refinery	Inorganic:	Heavy metals e.g. Mo, As, V, Hg, Co, Cr, Ni, Pb Ammonia Sulphur compounds Lime/Caustic Soda	Refining Process : products, residues, wastes.
	Organic:	Coal tar derivatives (See Chemical Works) Zinc aryls and alkyls	
Pharmaceutical	Inorganic:	Se, Cr, Zn, Hg, Cd, Mg, Cyanide Inorganic chemical preparations Sulphates	Fermentation, extraction and chemical synthesis, using a wide range of feedstocks and solvents.
	Organic:	Chlorinated solvents Insecticides e.g. hexachlorocyclohexane and malathion Surfactants Fats/Greases Coal tar derivatives (See Chemical Works) Vegetable tissues	
Power Stations and Large Boiler Houses	Inorganic:	Ash (high pH) Amines As, B, Cr, Cu, Hg Sulphide, Sulphate Trace metals Acidity and Alkalinity Asbestos	Energy generation from coal/coke Coal/coke storage Asbestos in insulation.
	Organic:	Coal tar derivatives (See Chemical Works) Coal/coke dust PCBs Wood preservatives (See Timber Products) Alcohols	 Stacks, cooling towers, transformers.
	Gases:	Hydrogen sulphide Methane Carbon dioxide	

Site Use	Potential Contaminants		Notes
Pulp and Paper	Inorganic:	Cr, Pb, Mn, Zn Chlorine compounds Sulphides/sulphates/sulphites/bisulphites Phosphorus Nitrogen Resin acids Aluminium	Mainly chemical pulping processes. De-inking
	Organic:	Biocides Dyestuffs Degeneration products of lignin Phenols Organochlorine compounds Fibrous organic matter	 Paper bleaching
Railway Yards and Railway Land	Inorganic:	Cu, Pb, As, Hg, Ni, Mn, Cr, Cd, Zn, Mg Sulphates Sulphides Cyanides Chlorides Asbestos	Workshops. Fill material. Wash-down water storage tanks.
	Organic:	Mineral oils Coal tar derivatives (See Chemical Works) Herbicides e.g. Simazine, atrazine, paraquat PCBs Chlorinated and non chlorinated solvents	Lubricants, transformers, weedkillers.
Scrapyards	Inorganic:	Pb, Zn, Cu, Cd, Ni and other heavy metals Cyanides Sulphates Acids Alkalis	Site Operations. Metals may be present as dust.
	Organic:	Various organic compounds Oils	
Sewage Works and Farms	Inorganic:	Cd, Pb, Zn, Cu, Cr, Ni, As, Hg, Al, Fe Chloride Fluoride Sulphate/Sulphide Ammonia Nitrate	Sludge, treatment chemicals, trade effluent.
	Gases:	See Landfill Sites	
	Microbiological:	Pathogenic bacteria and virus	Sewage residues.

Site Use	Potential Contaminants		Notes
Tanneries	Inorganic:	Al, Si, As, Cr Sulphides Chlorides Calcium hydroxide Acid ammonium salts Sodium carbonate Mercuric fungicides Insecticides e.g. borax	Pre-tanning, tanning and finishing processes.
	Organic:	Mineral oils Solvents, possibly chlorinated Phenols PCP Biocides	
	Microbial:	Possible anthrax if skins are imported or very old site.	
Textiles and Dyes	Inorganic:	Pb, As, Cd, Zn, Ti, Sodium dichromate Sulphides of barium, chromium, Chlorine and other bleaching agents Cu, Pb and Ni Sulphate	Spinning, weaving and finishing processes (including dyeing)
	Organic:	Solvents and organic acids e.g. organic dyes Urea derivatives Rot and moth proofing chemicals e.g. dieldrin	
	Microbial:	Possibly anthrax associated with wool industry	
Timber Products and Treatment	Inorganic:	Cu, Zn, B, Hg, Cr, As, Fl Ammonium salts	Timber production treatment and preservation processes
	Organic:	Coal tar derivatives (See Chemical Works) Organomercury Tributyl tin oxide Zinc and Cu napthenates Emulsions and sludges accumulated in storage tanks organic solvents Pesticides and fungicides e.g. aldrin, dieldrin, PCP, DDT and Lindane	

MAJOR SOURCES OF AERIAL PHOTOGRAPHS FOR UNITED KINGDOM

1. Government

Air Photo Cover Unit
Ordnance Survey
Romsey Road
Maybush
Southampton S09 4DH

O.S. of Northern Ireland
Department of the Environment
(Northern Ireland)
Colby House
Stranmills Court
Belfast BT9 5BJ

National Monuments Record
Air Photography Unit
Royal Commission on Historical Monuments for England
Kemble Drive
Swindon
Wiltshire SN2 2GZ

Royal Commission on Ancient and Historical Monuments
of Scotland
Central Register of Air
Photography of Scotland
John Sinclair House
16 Bernard Terrace
Edinburgh EH8 9NX

Welsh Office
Air Photographs Unit
Room 6-003
Crown Offices
Cathays Park
Cardiff CF1 3NQ

Royal Commission on Historical Monuments Wales
Eddeston House
Queens Road
Aberyswyth
Dyfed SY23 2HP

Ministry of Agriculture Food and
Fisheries Aerial Photographic Unit
Block B
Government Buildings
Brooklands Avenue
Cambridge CB2 2DR

2. Commercial

Aerofilms Limited
Gate Studios
Station Road
Borehamwood
Herts WD6 1EJ

BKS Surveys Limited
47 Ballycairn Road
Coleraine
Co. Londonderry
Northern Ireland
BT51 3HZ

Cartographical Services
(Southampton) Limited
Landford Manor
Landford
Salisbury
Wiltshire SP5 2EW

Engineering Surveys Ltd.
Reform Road
Maidenhead
Berks
SL6 8BU

National Remote Sensing Centre Ltd.
Barwells Business Centre
Arthur Street
Barwell
Leicester LE9 8GZ

Planning and Mapping Limited
17 Huffwood Estate
Brookers Road
Billinghurst RH14 9HR

3. Other Sources

Cambridge University Collection
of Air Photos
Mond Building
Free School Lane
Cambridge CB2 3RF

The National Association of Aerial Photographic Libraries has published a Directory of Aerial Photographic Collections in the United Kingdom [ASLIB, London, 1993]. This contains 372 entries for local, county, university and private air photo collections.

SUGGESTED CONTENTS OF FACTUAL AND INTERPRETATIVE REPORT

Factual Report

Suggested contents of the Factual Report for the CGI includes:

(i) Title page;

(ii) Description of the extent of work comprising the contamination ground investigation
- number of exploratory holes
- dates
- duration of work
- weather conditions
- method of exploration
- sampling strategy
- field test and on site measurements and procedures
- monitoring installations
- laboratory tests.

(iii) Data presentation and record sheets
- boring
- probing
- trial pitting
- in-situ measurements (including spiking surveys)
- field description of samples
- results of laboratory analyses.

(iv) Description of sampling, monitoring, and laboratory test methods including any reference to standards used;

(v) Quality control procedures including chain of custody records;

(vi) Key plan showing alignments and/or area covered by investigations;

(vii) Location plans showing positions of exploratory holes;

(viii) Photographic records.

(Boring logs, trial pit records, and location plans may also be repeated elsewhere in the ground investigation report).

Interpretative Report

The Interpretative Report should present an analysis of all the data collected, including a description of the methods used to assess the data.

The Interpretative Report dealing with contaminated land should preferably be a separate volume to the geotechnical (GI) interpretative report for the scheme. However, reference must be made to all geotechnical aspects of the scheme which are relevant to the areas of contaminated land (eg geotechnical parameters of 'natural' strata lying beneath the contaminated material).

The report should give an appraisal of the feasibility of constructing various engineering solutions for crossing the contaminated land, together with an assessment of any deleterious effect on construction materials.

The environmental impact of any feasible engineering solutions should then be assessed with respect to contamination.

Suggested form of report:

(i) Title page

(ii) Introduction

This should be a reference to the Scope and Object of the contract and a summary of the report contents.

(iii) Existing Information

This should summarise the sources of existing information including the results of the desk study used in the work and the range of data thus obtained.

(iv) Fieldwork

This should comprise a brief description of the fieldwork undertaken and should outline its purpose. It should also highlight any constraints which have affected the design of the investigation.

(v) Instrumentation and Monitoring

The nature, location and purpose of all instrumentation (eg standpipes, piezometers, gas monitoring) should be outlined, together with their purpose.

(vi) Laboratory Work

This should comprise a summary of the laboratory tests undertaken; together with a description of test methods, accuracy, precision and sensitivity.

(vii) Site Description

Location
Geology
Geomorphology (if appropriate)
Hydrology/Hydrogeology
History (ie former use)
- tipping history
- aerial photographs
- permitted materials
- anecdotal

(viii) Engineering proposals

(scheme specific)

(ix) Assessment of results. This is to include a detailed discussion of the procedures followed and reference data used to assess hazards and to estimate and evaluate the risks to construction and to the long term operation of the highway development. The significance of observed levels of contamination should be discussed. The assessment should lead to a list of known hazards with a description of the nature and extent of ground contamination revealed by the investigation.

(x) Precautions to be taken during construction and in the long term.

(xi) Special requirements for dealing with contaminated material and leachate during construction and in the long term.

(xii) Requirements for special measures to be incorporated into the design (eg sealed drainage systems, gas venting).

(xiii) Special requirements of Environmental Health Officer, Health and Safety Executive.

(xiv) Plan of site indicating sampling locations

(xv) Cross sections through site

(xvi) Long section through site.