2 SITE ASSESSMENT

Chapter contents

2 SITE ASSESSMENT

2.1 Introduction

Site assessment is the process by which all relevant information concerning a site is compiled and evaluated to enable the most appropriate reclamation proposals to be produced. This chapter describes the basic principles of site assessment, providing a framework for detailed assessments of specific aspects. The detailed assessment of specific issues are dealt with in later chapters (see Table 2.1).

Site assessment usually includes:

- a walkover survey;
- a desk study, with preliminary investigations;
- detailed investigations and surveys;
- analysis of the information collected.

The site assessment process should identify:

- risks to people or to the environment from the site in its present state;
- constraints on the future use of a site, such as poor ground conditions or areas of contamination;
- the opportunities presented by a site, such as ecological or wildlife value or the presence of structures of historical importance;
- structures which could be put to beneficial use;
- materials which could be put to beneficial use.

2.2 Preliminary planning

Site assessment and future site use are closely related, and a particular proposed site use will require the investigation of aspects of the site that are specific to the after-use concerned. For example, reclamation for

Table 2.1: Chapter location of site assessment methods

Chapter number	Assessment described
2	Ecology, landscape, structures, archaeology, contamination
3	Mine workings
4	Pre-closure site audit
6	Tip stability
7	Spoil combustibility
8	Feasibility of coal recovery
9	Expansion of slags
12	Water pollution
14	Suitability of materials for revegetation

public open space, or amenity woodland, will require the investigation of soils and water for their ability to support growth of suitable plants, whereas reclamation for industrial development requires the investigation of ground conditions for foundation design and to establish the presence and extent of buried foundations. Both uses would require the investigation of contamination and its potential detrimental effect on subsequent users of the site or other targets such as groundwater. Whilst it is important in the early stages of site assessment to maintain flexibility over reclamation proposals some indication of proposed site use will assist the site assessment process and enable appropriate assessments to be made without wasting time and resources.

Reclamation objectives and site after-use proposals can be expressed in the form of a 'masterplan'. A masterplan is a document which can be a combination of drawings and text and which provides a framework for detailed site assessment and subsequently for the design of reclamation works.

2.3 Desk study and preliminary investigations

A desk study involves the collection and collation of all relevant information relating to the site and its surroundings. Sources of this information include:

- maps and plans;
- aerial photographs;
- industry records;
- mining records;
- results of earlier investigations;
- utility companies.

Organisations such as local authorities should be consulted, and local knowledge should be utilised as much as possible, for example by interviews with people living near the site. Past employees of a former industrial facility are particularly useful as sources of information.

The information obtained in the desk study will include:

- planning policies related to the site and the surrounding area;
- land ownership and other rights over land, including rights of way;
- current land uses, of the site and surrounding land;
- current infrastructure (roads, railways, utility services);
- information on geology, hydrology, hydrogeology, soils and climate;
- positions of shafts and mine workings;
- all former uses of the site and surrounding land;
- layout of plant and former process activities;
- waste disposal practices and licences issued;
- industrial archaeology including any designation or listing of particular site features;
- any reports on the ecology of the site.

Visits to the site should complement the desk study and provide information on the current status of the site and surrounding land. The following aspects, which serve to highlight the complexity of derelict industrial sites, should be considered during the visits:

- current land use;
- character of the surrounding landscape;
- the visual impact of the site;
- the presence of buildings, with an assessment of their structural soundness, their potential for reuse and their historic value;
- the presence and condition of other structures *e.g.* walls, culverts, bridges;
- the nature of materials at the surface, particularly whether they impede investigative excavations at the site;
- the presence or absence of vegetation, the nature of the vegetation and an assessment of its ecological and landscape value;
- deposits of waste materials, for example colliery spoil or slags and other materials such as stone, bricks or hardcore;
- the existing landforms and the constraints or opportunities they present;
- soil or soil substitute resources available on site;
- signs of contamination, for example unusually coloured materials, odours, lack of vegetation, presence of tanks or drums which may have held, or still hold, hazardous materials;
- surface hydrology;
- the presence of utilities (such as water or gas mains, electricity cables, sewers).

In general the presence of contaminating substances derives from activities and processes which were or may still be carried out on a site. Much information on the location of contamination will be gained from a pre-closure site audit (see Box 4.5). Frequently in the past a pre-closure site audit has not been undertaken, and access to the site for the purposes of site audit was only possible after closure and often after demolition had already taken place. In many cases sites have been levelled-off, removing all significant landmarks, and leaving imprecise records of the works which may be misleading. At coal carbonisation sites, such as coking works and gas works, the presence of above-ground by-product storage and process facilities provides invaluable information for those required to design and undertake a site investigation. Closure of the works and the demolition and/or removal of process structures increases the difficulties in making an investigation appropriate, well targeted and cost effective.

The preparation of a reclamation scheme will generally involve a team of people from different disciplines. It is important that all members of the team are familiar with the site at an early stage. To bring together and brief the team at or before the preliminary investigation stage is likely to enhance the efficiency of the site assessment and reclamation design process.

A critical appraisal of the information gathered by the desk study and preliminary investigations will enable identification of likely constraints on, and opportunities for the reclamation and reuse of the site. For example it may be possible to predict likely areas of contamination, make an estimation of quantities of spoil, or assess the potential for re-use of buildings. This analysis will enable development of the reclamation proposals to proceed in a well informed way, and to include the preparation of broad budget costings as part of a masterplan.

2.4 Detailed investigations

2.4.1 Introduction

Detailed investigations should aim to identify and quantify the constraints or opportunities which, on the basis of past use, are present in any particular area of a site and which will impinge on the proposed use of the site. Typically the team of investigators will include civil, structural and geotechnical engineers, environmental scientists, landscape architects and topographical surveyors, although more specialised disciplines will be required in some cases.

The desk study and preliminary investigations will have identified aspects in need of detailed investigation. Some of these aspects will only require investigation if certain site uses are planned, whilst others will require investigation whatever the site use. The latter may include the stability of tips, surface water and groundwater pollution arising from contaminated ground and air pollution and ground instability caused by burning colliery spoil or unstable mine workings.

2.4.2 Topographical survey

An accurate topographical survey is essential baseline information. The establishment of control stations for the site before any demolition takes place is invaluable. There is then a clear and unambiguous correlation between the site as it was in its former use and its condition when clearance is completed. The features which should be included in a topographical survey are shown in Box 2.1.

Box 2.1: Features included in a topographical survey

A topographical survey should record the following:

- permanent and seasonal watercourses;
- drainage systems - open and closed;
- sinks and issues of water;
- tracks, paths and boundaries;
- shafts, adits and tunnels;
- buildings and other structures;
- major vegetation zones;
- positions of trial pits, boreholes and soil probes;
- positions of other sampling points;
- access roads;
- railways and canals;
- spoil heaps;
- slag heaps;
- lagoons;
- contours.

2.4.3 Ecological survey

The detailed investigations will include further study of the matters considered in the preliminary investigations. These include assessment of the existing vegetation present on the site (see Box 2.2) and its ecological value (see Box 2.3).

2.4.4 Visual assessment

Box 2.4 discusses the assessment of the visual characteristics of a site. Assessment of the visual characteristics of a site requires a rational, professional approach, and involves description, analysis and evaluation of the landscape.

Visual assessment is important because it equips the design team with information which is needed to take full advantage of the visual assets of the site, and to cater for its visual problems.

Box 2.2: The value of existing vegetation

Most derelict or abandoned sites have some vegetation, either that which has colonised abandoned areas or that which survived through the operational life of the site. This vegetation is worthy of examination since existing vegetation:

- can indicate the characteristics of the site and guide revegetation;
- provides a habitat for common or uncommon species of plants and animals;
- provides a reservoir from which plants and animals can recolonise the reclaimed areas of the site;
- may possess a tolerance of hostile site conditions, which can be utilised by propagation;
- lends visual maturity to the site;
- may provide a buffer between nearby residents and major reclamation works;
- may protect spoil materials from erosion or instability;
- retention reduces expenditure on the establishment of new vegetation.
- may include invasive species such as Japanese Knotweed (*Fallopia japonica*), which may be spread by reclamation earthworks, and for which control measures will need to be specified at the design stage.[201, 212]

Where examination suggests that existing vegetation can play a useful role within the reclamation objectives for the site, it should be protected from disturbance and integrated with the design of the landform and revegetation works. The existing vegetation may require additional management works such as species enrichment, control of invasive weeds or the improvement of fertility, in order that reclamation objectives are fulfilled. Conversely, the objectives of reclamation may be modified to take in the conservation of valuable existing vegetation.

Box 2.3: Ecological assessment

Ecological assessment is the process of assessing the 'ecological value' of an area of land. In the context of site assessment prior to reclamation work, the aim of ecological assessment is to assess what value the site has so that the information may aid decision making about how the site is treated. The process of ecological assessment is broadly the same throughout Europe although some of the criteria for assessment may be given different emphasis in different countries. Typically an assessment will involve:

- gathering of background ecological information on the site and on similar sites;
- field survey and annotation of maps with different habitat types and species of interest;
- evaluation of the ecological value of the site and its component parts;
- placing of the site in a local, regional and national context in terms of its value.

The most frequently used criteria for placing value on a site are as follows:

- diversity;
- rarity;
- area;
- threat of human interference;
- amenity value;
- education value;
- recorded history.

An ecological assessment will also provide information on the nature of the materials on site. A botanist will be able to make assessments of the contamination and nutrient status of the materials on the basis of the vegetation composition. Such information will aid in deciding if suitable soil-forming materials are available on site and if any materials should be set aside as a 'seed bank' for a reclamation scheme. Similarly recommendations may be made about the protection of existing species, measures to assist their spread and opportunities for habitat creation.

Box 2.4: Visual assessment

It is important to consider the visual qualities of the surroundings of a site, as well as the site itself, so as to:

- study the appearance of the site and its features from outside its boundaries;
- appreciate the character of the landscape into which the site must be integrated and identify the local 'sense of place'.

The assessor should seek to analyse what gives particular character to the setting and the site, distinguishing the positive and negative aspects. Areas of common character should be identified on a plan. This gives a framework for action to build on positive aspects and to deal with the negative ones.

Visual assessment frequently examines the following:

- the 'visual envelope' of the site, *i.e.* the area which can be seen from the site, or which provides views of the site;
- noteworthy views out of the site;
- views of the site and its features, together with assessment of its visual impacts, considering how many people can see it, from how far away;
- the nature of all views, *i.e.* panoramas;
- description of landform, land-use patterns, vegetation (see Box 2.2), the built environment and any special natural or manmade landscape features, both on and off site;
- identification of remnants of the pre-industrial landscape within the site and any other features which may be worth preserving, to add character and maturity to a scheme;
- description of the emotional responses to the site and its setting e.g. does it give a feeling of enclosure or exposure and is it thus stimulating or oppressive?

2.4.5 Structural integrity of buildings

Where buildings or other structures exist on a site an assessment of their structural integrity should be made by a structural engineer to determine whether they are in a safe condition and whether they can be reused. Box 2.5 indicates the types of defects which can be caused by differential movements beneath buildings and the possible causes of those movements.

2.4.6 Ground conditions

Investigation of the nature of materials below ground level must be undertaken at former industrial sites. These ground investigations may be used to obtain information on the following:

- the location and condition of underground structures, foundations, cavities, shafts, mine workings *etc.*;
- a geotechnical description of ground conditions to determine foundation requirements;
- the nature and location of contaminated ground;
- groundwater levels, flow and contamination;
- stability of spoil heaps and waste tips;
- potential of materials as a growth medium for vegetation.

This investigation is multifaceted and to avoid duplication of effort it is important that there is coordination between the different disciplines. A variety of methods, both invasive and non-invasive, are available to the practitioner for the investigation of sub-surface conditions. These methods are discussed in detail in the following section.

Box 2.5: Structural assessment

Buildings may show signs of distress from relative movements of the building fabric. Distress can manifest itself in the following defects, which tend to be concentrated around or radiate from an area of maximum stress:

- tapered cracks indicating sagging or hogging modes of failure;
- inclined cracks usually associated with movement at the extremity of the building;
- vertical and horizontal cracks especially at relatively weak areas around openings and at damp proof course level;
- sloping lintels;
- bulges and lack of verticality in walls;
- slopes in floors;
- doors and windows jamming in distorted frames.

The possible causes of movements include:

- differential settlement due to uneven consolidation of clay soils;
- subsidence of foundations;
- heave due to frost, a rising water table or expansive chemical reactions;
- instability of sloping ground.

Subsidence may be caused by:

- mining activities below or adjacent to the building;
- settlement of filled ground;
- water movement under the building from natural sources or from broken services;
- water abstraction from ground below the building;
- shrinkage of clays;
- collapse of solution cavities;
- excavation adjacent to the building;
- earthquakes.

2.5 Techniques of ground investigation

2.5.1 Trial pits

The excavation of trial pits is a relatively inexpensive method of ground investigation, which can provide valuable information on subsurface characteristics.

Trial pits are excavations carried out from the ground surface. The advantage of trial pits is that they allow direct visual examination of the material below ground level and the taking of large samples of solid materials and groundwater. Box 2.6 shows the types of information which can be obtained from a trial pit. Sampling and chemical analysis are discussed in Sections 2.6.2 to 2.6.5.

Site personnel should not enter trial pits without first ensuring that it is safe to do so. Precautions such as shuttering are generally necessary to prevent collapse of pits of more than 1m deep. Before entering a pit, or any other enclosed space, monitoring of the atmosphere should be carried out to ensure that toxic gases or vapours are not present. Reliable and accurate gas monitoring equipment should be used for this purpose.

Machine dug trial pits can extend to 6m below ground level although 3-4m is often sufficient for observation of ground conditions and the collection of samples. The depth of unsupported trial pits is frequently limited by the collapse of the sides of the trial pit.

Trial pits can easily be extended lengthways into trenches to determine the extent of any visible materials of interest. If concrete or other hard materials are present, either at the surface or at depth, these may require breaking with a percussion breaker.

The excavation of trial pits causes considerable disturbance of the ground. To avoid settlement following reinstatement, trial pits should be refilled and compacted in layers, with the addition of imported material where

Box 2.6: Trial pit logs

Trial pits can be used to obtain a wide range of information and should be recorded by photographs of the exposed ground profile and by a written log. The trial pit log should include observations on the following:

- the nature of the materials present according to depth e.g. colour, soil type, whether fill materials or natural ground;
- subsurface structures e.g. foundations of former buildings, pipes, ducts;
- location and rate of flow of groundwater seepages;
- standing levels of groundwater, at specified times after pit excavation;
- the location of samples taken.

necessary. Where heavily contaminated materials are excavated these should never be left exposed at the surface after infilling of pits. Care should also be taken to avoid the introduction of contaminated materials into previously uncontaminated strata when backfilling trial pits. This is particularly important when those strata contain groundwater which could become contaminated and thus cause pollution over a much wider area. If necessary contaminated materials should be removed from the site rather than used to backfill the trial pit. Generally, trial pits should not be left open if the site is unattended, but should be backfilled as soon as possible after inspection.

2.5.2 Boreholes

Introduction

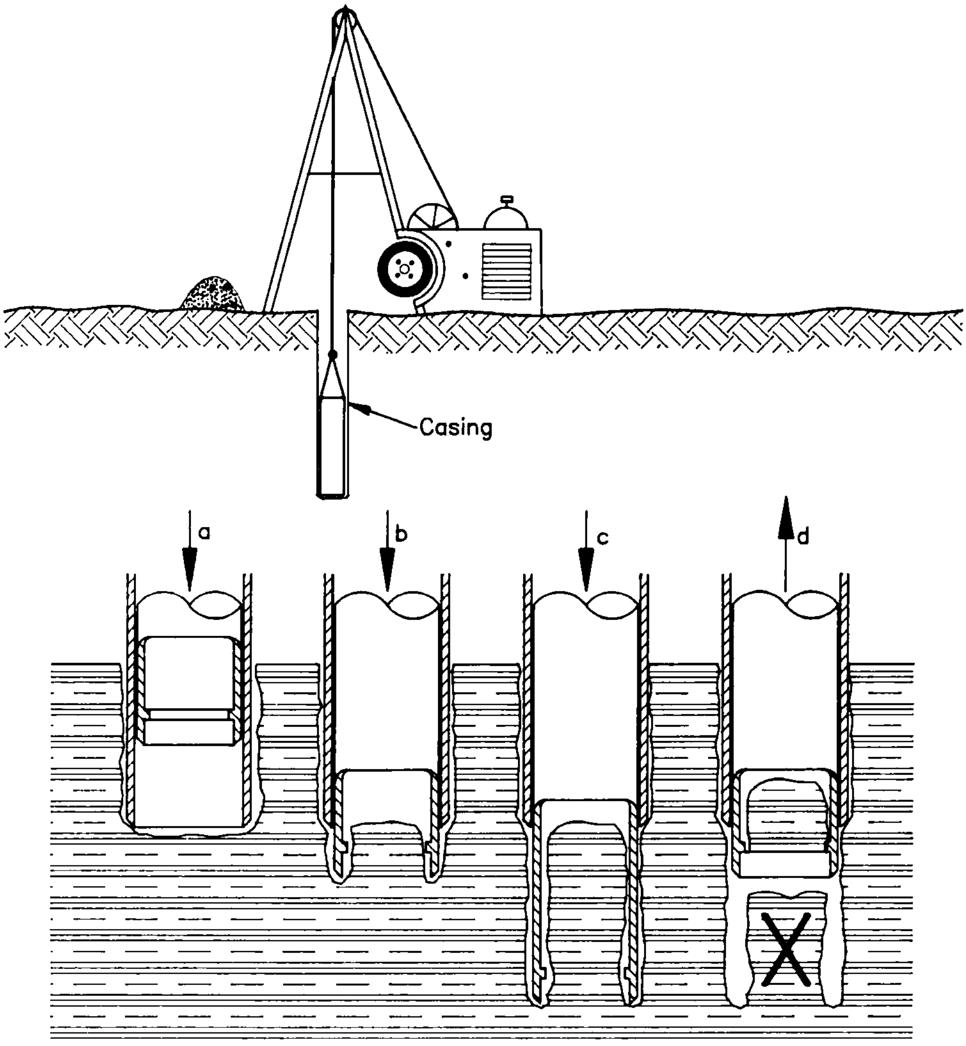
Boreholes are the most common method of investigation of ground conditions beyond the reach of trial pits. They can also be used for shallow investigations when the disruption caused by trial pits would be unacceptable.

Cable percussion

Cable percussion, also known as shell and auger, is the most frequently used technique in soils and weak rock (see Figure 2.1). The drilling tool, an open-ended tube, is driven into the ground by repeated lifting and dropping. When full of soil or other subsurface material the tool is brought to the surface and emptied. Samples may be obtained in this way. In cohesive soils such as clays and silts the tube is known as a clay cutter. A core of undisturbed material may be obtained by discarding the outer portion of material brought up by the clay cutter. In sands and gravels the tube has a flap valve to retain loose material during lifting. This tube is known as a shell or bailer and its use requires the borehole to contain sufficient water to cover the lower part of the shell. In dry ground conditions water may have to be added to the borehole as a lubricant. Chisels are used to break up rocks or other hard layers. Flush screw-thread steel casings are driven into the ground in wet, very soft, or loose soils to line the borehole as it advances. Shell and auger boring is a fairly simple and economic technique which can provide accurate information on ground conditions. Borehole depths of 20 to 30m are readily achievable using this technique, providing there are no obstructions, and depths in excess of 50m are possible in favourable conditions.

Rotary techniques

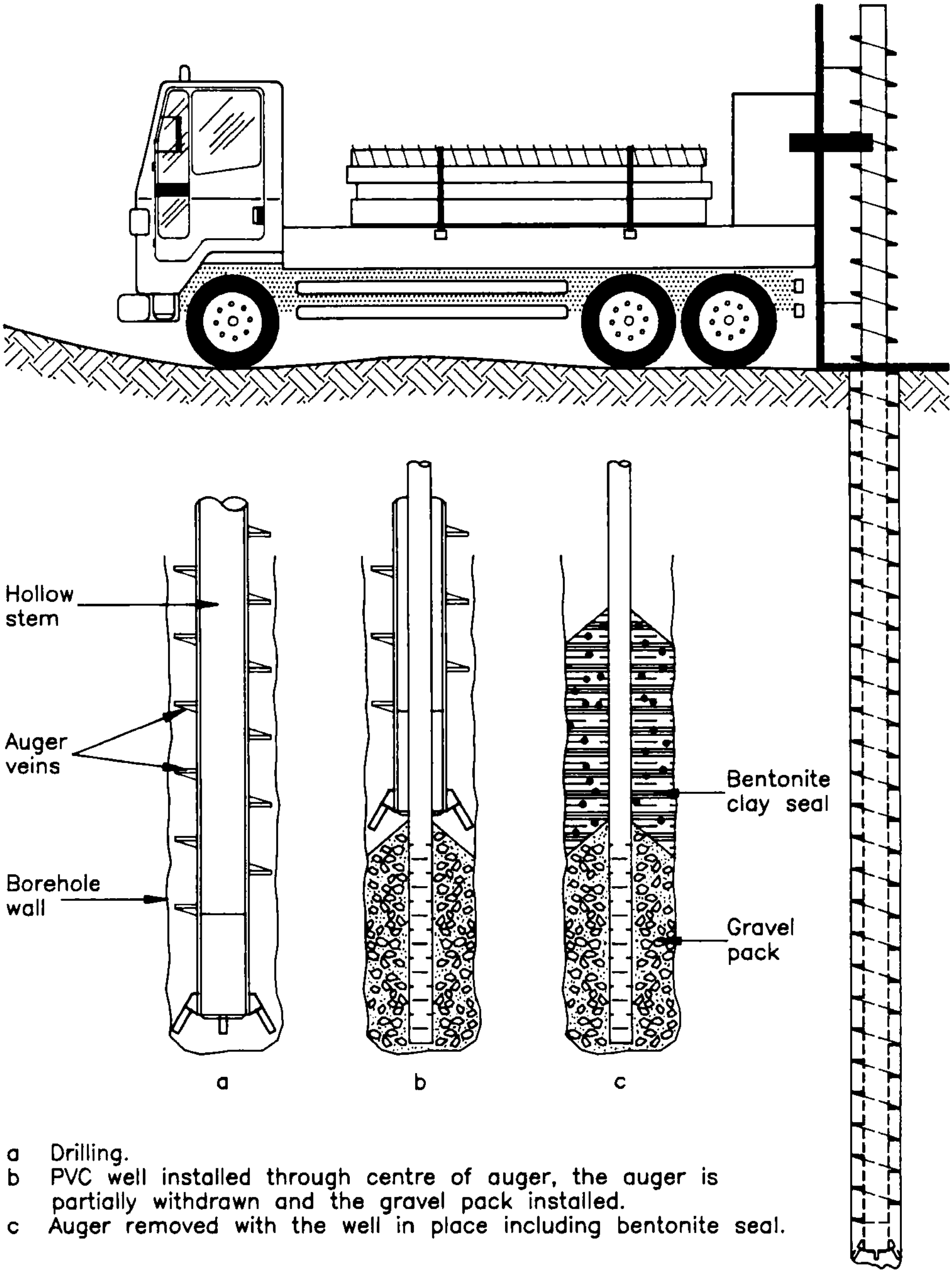
The alternative to percussive methods are rotary techniques such as rotary augers and rotary drilling. Rotary augers (see Figure 2.2) are used in soils but are not suitable for thick deposits of granular materials or for soils containing cobbles or boulders. The equipment used is more expensive than for cable percussion, and augering is a less suitable technique for obtaining accurate information on ground conditions as materials from different strata become mixed as they are carried to the surface by the auger. However, rotary augering is far quicker than percussive methods so it is frequently used when ground conditions are already known and rapid installation of groundwater or gas monitoring



a Clay cutter on first downward stroke.
b End of first stroke. Clay cutter has penetrated base of borehole.
c Repetition of strokes a and b causes clay cutter to penetrate further.
d Retaining ring eventually shears soil at base. Clay cutter is raised to the surface for emptying. The soil at X is disturbed.

Clay cutter action

Figure 2.1: Cable percussion (after Weltman and Head, 1983[255])



a Drilling.
b PVC well installed through centre of auger, the auger is partially withdrawn and the gravel pack installed.
c Auger removed with the well in place including bentonite seal.

Figure 2.2: Rotary augering and installation of PVC well

boreholes is required. Undisturbed samples may be obtained using hollow-stemmed augers.

Rotary drilling (see Figure 2.3) is used in hard rock strata and includes rotary core and rotary percussive techniques. Rotary core drilling is used to obtain core samples and provide detailed information on rock strata. Rotary percussive drilling methods are used for probe drilling or the investigation of mine workings (see Section 3.3) and are more economical than core drilling although they are of limited use in obtaining samples. Sometimes the two drilling methods may be used together by penetrating to the required depth using rotary percussion and then using rotary coring to obtain core samples. A drilling fluid, such as water, or air, foam or a drilling mud, is required to cool and lubricate the drill bit and flush the fragments of rock to the surface.

Monitoring wells

Boreholes can be fitted with stand pipes or piezometers for measurement of groundwater levels, obtaining samples of groundwater or for monitoring gases. Design of wells for groundwater monitoring should ensure that only water from the stratum of interest is allowed to enter the well. For example, when monitoring groundwater in natural sands beneath fill materials, slotted pipe should be used within the sands but not through the depth of the fill material above. In contrast, in order to monitor gases produced by the fill materials, slotted pipe must be used within the fill.

Boreholes in contaminated land

When boreholes are used at contaminated sites, care is needed to ensure that the boreholes do not allow contamination to spread into underlying uncontaminated strata. Where a confined aquifer is present beneath contaminated ground, boreholes should not extend into the aquifer. Where boreholes are used for sampling of soils and groundwater in order

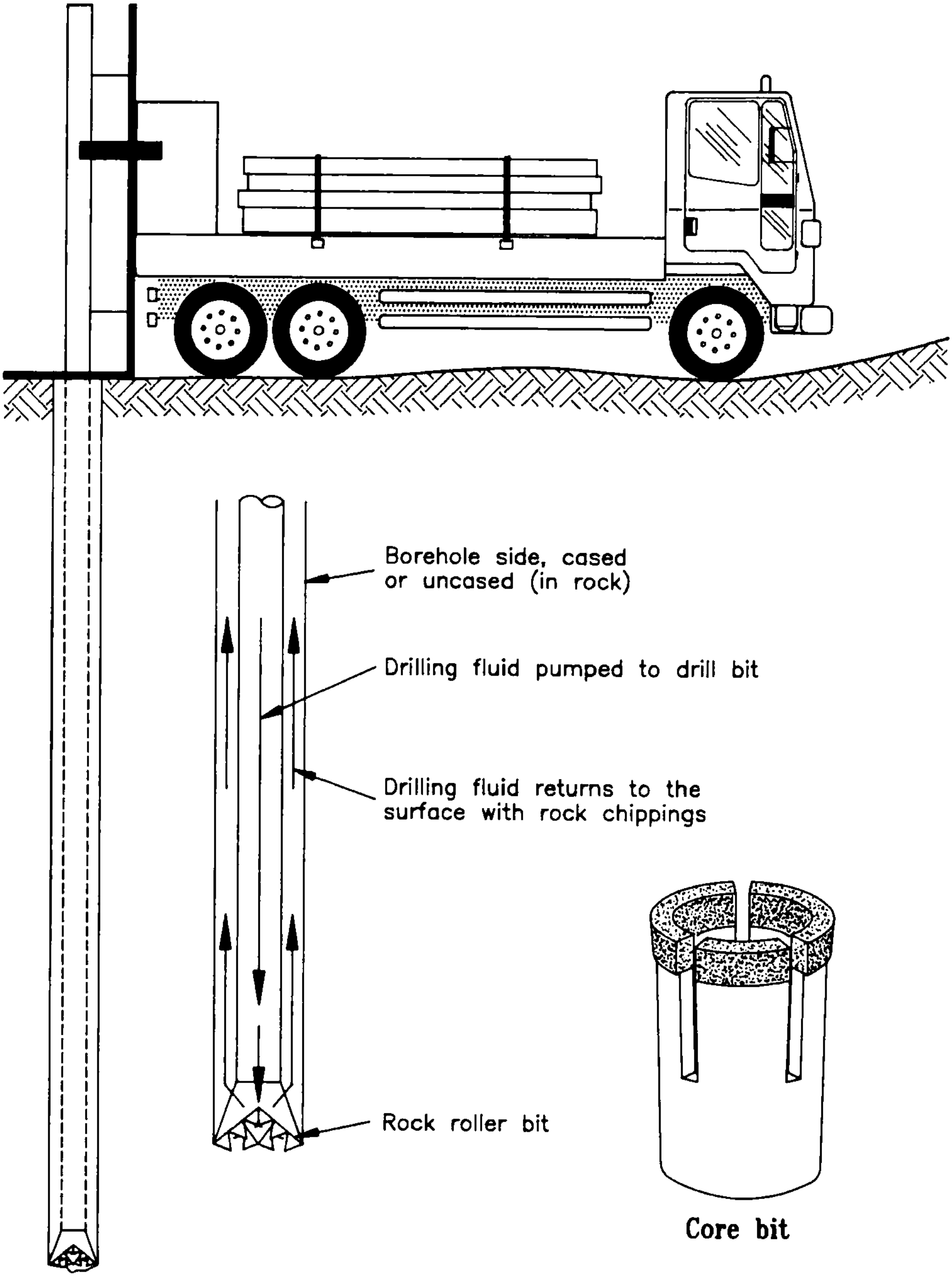


Figure 2.3: Rotary drilling (after Weltman and Head, 1983[255])

to assess contamination the procedures shown in Box 2.7 should be followed.

Geotechnical tests

During borehole drilling, tests can be carried out to determine geotechnical characteristics of the ground. Penetration tests, where a sampling tube is driven into the soil for a set distance by repeated blows of a drop hammer, give an indication of the strength of the stratum. Penetration tests are frequently carried out during cable percussion drilling. The permeability of strata may be measured by pumping water out of a borehole and measuring the rate at which it fills (rising head test) or by pumping water into the borehole and measuring the rate of fall (falling head test). A variety of laboratory tests may be carried out on samples collected during the ground investigation to provide information on the geotechnical properties of materials. Such tests include moisture content, liquid and plastic limits, bulk density, particle size and, for undisturbed samples, shear strength and compressibility.

Box 2.7: Measures to avoid introducing contamination whilst boreholing

The following precautions should be taken to avoid cross contamination whilst boreholing:[204]

- equipment should be cleaned before moving from contaminated to less contaminated areas;
- the use of lubricants should be avoided;
- air filters should be fitted to the exhaust of the drilling rig and to the air compressor where air flushing is used;
- drilling fluids should be used only where absolutely necessary, when water of mains quality should be used, a sample of which should be taken for analysis, and the quantity used recorded;
- packing media used around stand pipes or piezometers should be inert and free of impurities.

2.5.3 Soil probes

A variety of small diameter probes have been developed in response to a demand for small, mobile rapid machines which also have the advantage of causing less disturbance than traditional trial pits and boreholes. Probes may be the preferred method of ground investigation where contamination makes it desirable to minimise contact of personnel with materials in the ground, or where the contamination is volatile and disturbance caused by trial pits is likely to result in loss of volatile compounds from materials sampled.

Probes may be used for obtaining information on soil type, sampling of soil gas and obtaining samples of soils and groundwater. Depths of several tens of meters can generally be achieved. Information on soil type can be obtained from cone penetration testing. A probe fitted with a cone tip is driven into the ground at a constant rate and continuous measurements made of cone tip resistance and side friction. The relationship between these two measurements is dependent upon soil type. Adaptations to the standard cone penetration equipment allow measurements of porewater pressure, permeability, conductivity, pH, redox potential and temperature.[247]

Soil gas surveys have been one of the most frequent uses of soil probes. The total concentration of volatile compounds *e.g.* benzene and associated compounds at coal carbonisation sites, can be rapidly measured using portable instruments such as flame ionisation detectors. On-site gas chromatography can be used to obtain information on the nature of the volatile compounds present. The collection of soil samples for subsequent laboratory analysis is, however, necessary to obtain soil concentrations of specific compounds.

2.5.4 Geophysical techniques

Geophysics provides a range of non-invasive techniques for ground investigation which rely on differences in physical properties between different materials. Techniques include ground probing radar, electrical resistivity, seismic refraction, magnetometry and electromagnetics. Further information about these techniques is given in Box 2.8. Such techniques can be used for locating buried foundations, underground voids, tanks, shafts and mine workings and, in some cases, areas of contamination. The techniques are generally fairly rapid but require specialist interpretation. Results can be ambiguous, requiring confirmation by excavation or other techniques. Geophysical techniques do, however, provide a means by which large areas can be covered quickly, directing future ground investigations to the areas most likely to be of interest.

Box 2.8: Geophysical techniques

Ground probing radar
Reflection of electromagnetic pulses of 100-1000 MHz from sub-surface features. The equipment is highly mobile and can be towed at speeds of several km/hour. Depth penetration is poor, sometimes as little as 1m in water-saturated or clay materials.

Electrical resistivity
An array of electrodes is moved across the site to map changes in resistivity, such as may be caused by areas of contamination.

Seismic refraction
Measures travel times of seismic waves, typically induced by sledge hammer blows. Can give information on strata to 20-30m depth, but is ineffective when overburden is dry or unconsolidated.

Magnetometry
Measures changes in magnetic field caused by ferrous objects or differing magnetic susceptibility of geological units.

Electromagnetics
A transmitter and a receiver are moved across the site, while maintaining a constant distance between them. Variations in subsurface electrical conductivity, due to variations in groundwater levels, or the presence of metallic objects, are mapped. Interference may be caused by buildings, power lines, electrical storms and fences.

2.6 Investigation of contamination

2.6.1 Nature of contamination

Contaminated land has been defined by the NATO Committee for Challenges to Modern Society as:

> "Land which contains substances that, when present in sufficient quantity or concentrations are likely to cause harm directly or indirectly to humans, the environment or on occasions to other targets."[223]

Contamination of the ground is associated typically with waste materials, some of which will have been used as fill to raise ground levels, or have been simply disposed of on site. Examples include metals in ashes, slags or flue dusts, and cyanides and sulphates in spent oxide from the purification of gases after coal carbonisation (see Section 10.2).

Contaminants may migrate from the wastes into surrounding uncontaminated materials. The extent of such migration is dependent on the nature of the waste materials and on the mobility of the hazardous substances in the surrounding ground. Contamination may also arise where mobile substances, particularly liquids, have been introduced into the ground through leaking pipes or tanks or through spillages during the course of on-site operations or site demolition. Unlike waste materials which can be identified visually, contaminated natural ground may be visually indistinguishable from uncontaminated ground. The source of mobile contamination may be located outside the boundaries of the site under investigation. The nature of the contamination typically found at coal and steel sites is discussed in Chapter 5 (colliery spoil), Chapter 9 (iron and steel) and Chapter 10 (coal carbonisation), whilst methods for treating contamination are described in Chapter 11.

2.6.2 Sampling strategy

There is always a degree of uncertainty associated with investigations of contamination as it is impractical to excavate the whole of a potentially contaminated site and analyse all of the materials therein to determine the concentration of contaminants present. Critical decisions have to be made with regard to the number and spacing of samples taken so as to obtain information on the contamination status of a site which provides the degree of certainty required. The degree of certainty will be increased by basing these decisions on information, obtained during the desk study, concerning the location of contaminating activities and waste disposal practices. The degree of certainty in contamination investigations is often expressed as the chance, or statistical probability, of finding a 'hot spot' of contamination, that is, a concentrated point source. The statistical probability is dependent on the sampling pattern and the frequency of sampling which are discussed in the following paragraphs.

Sampling pattern

There are three basic approaches to the pattern of sampling:

- **Judgemental**: samples are deliberately taken at certain locations selected on the basis of prior knowledge of contaminant distribution. Such sampling is very unlikely to produce samples which are representative of the site as a whole but it is an efficient way of obtaining information on the concentration of contaminants in an area known to be heavily contaminated, or the extent of migration of a contaminant from a known source.
- **Systematic**: sampling locations are defined by a grid system, generally a square grid (see Figure 2.4 (a)). This is easy to set out on site and is generally the method chosen where there is little prior information on the location of contamination. However, if the pattern of contamination coincides with the pattern of the grid, the samples obtained will not be

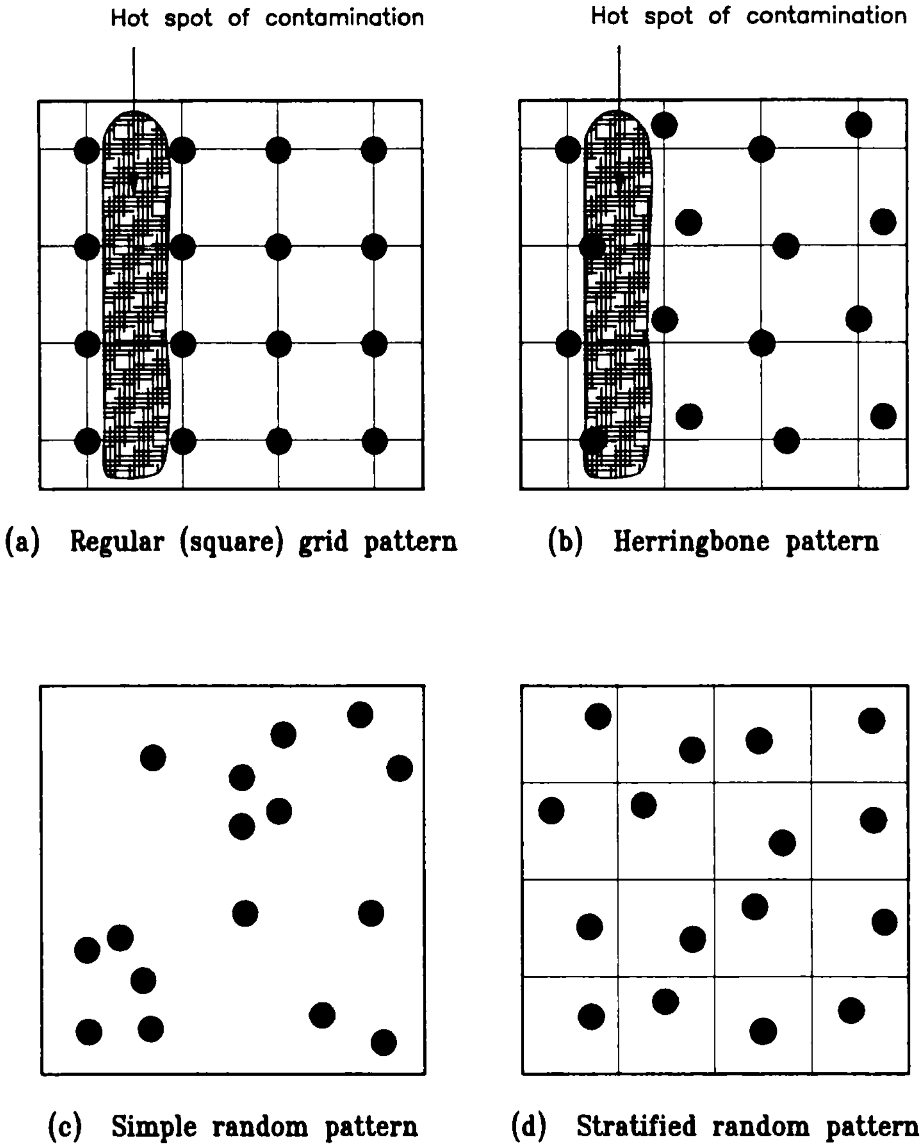


Figure 2.4: Sampling patterns for contaminated land

representative of the site as a whole. For example, elongated 'hot spots' of contamination which are parallel to the grid lines and fall between them will be missed altogether. The risk of this can be considerably reduced by using a herringbone rather than a simple square grid pattern, as shown in Figure 2.4(b).[91]

- **Random**: mathematically determined random sampling allows statistical analysis of results to be undertaken, although the variation between individual data points after sample analysis, especially with regard to chemical analytical data, is often so large as to make meaningful statistical interpretation impossible. In its simplest form, where sample points are placed randomly over the whole site, random sampling is inefficient in that unless a very large number of samples are taken there may be substantial areas where no samples are taken at all (see Figure 2.4(c)). More sampling locations are thus required to give the same probability of locating a 'hot spot' of contamination than with systematic sampling. By dividing the site into a number of areas (*e.g.* equal-sized squares) and placing a sampling location randomly within each area, less sampling points are needed than for simple random sampling. This is known as stratified random sampling and is shown in Figure 2.4(d). An element of judgemental sampling may be introduced by varying the relative sizes of the areas according to prior knowledge of the distribution of contaminants across a given site.

Frequency of sampling

A rational method of deciding sampling frequency is based on the following:

- the maximum size of a 'hot spot' which, if it is not discovered during the site investigation, would not cause unmanageable problems during later development of the site;
- the required degree of certainty of finding such a 'hot spot'.

For the herringbone sampling pattern the number of sampling locations needed to ensure a 95% probability of hitting a target 'hot spot' is given by the equation:

$$N = \frac{kA}{a}$$

where: N is the number of sampling points
A is the total site area
a is the area of the target 'hot spot'
k is a constant which depends on the shape of the target as follows:

circular target	$k = 1.08$
plume-shaped target	$k = 1.25$
elliptical target	$k = 1.80$

An assessment thus has to be made of the likely shape of the target in order to calculate the sampling frequency.[91]

Formulae for sampling frequency which reflect "current practical experience with soil investigation rather than considerations relating to the statistical reliability of pronouncements regarding the soil pollution of a site" are given in the Dutch draft standard for exploratory site investigations.[175] For sites where pollution is not suspected intensive sampling and analysis for a wide range of possible pollutants is necessary to have a reasonable chance of finding previously unknown pollution. Sampling should be done according to a systematic sampling pattern, with the number of sampling locations for near surface samples, n, given by:

$$n = 10 + 10A$$

where A is the total site area in hectares. Where the preliminary desk study has suggested that pollution is present but that its distribution is homogeneous the number of sampling locations is given by:

$$n = 5 + A$$

Where contamination is thought to arise from known point sources, four sampling locations per point source are recommended, with at least one groundwater observation well per point source. Where the locations of the point sources are not known, the recommended number of sampling locations is given by:

$$n = 4 + \frac{A}{a}$$

where a is the estimated area of contamination in hectares.

Depth of sampling

It is generally necessary to know how the concentrations of substances vary with depth, so at each sampling location several samples from various depths will need to be obtained. The British Standard Draft for Development, "Code of Practice for the identification of potentially contaminated land and its investigation", DD175,[43] recommends that at least three samples are taken at each sampling point, one to represent the surface and near surface layers, the second to represent the greatest depth of interest and the third at a random intermediate depth. However, more samples may be necessary to achieve the objectives of:

- obtaining representative samples of all types of waste materials present at a given surface location;
- obtaining samples of natural materials in order to enable an assessment of the migration of contaminants.

The Dutch Draft Standard for exploratory surveys,[175] recommends sampling the top soil (or the top 0.5m), then taking three samples of the subsoil one for each interval of 0.5m down to 2m below ground level. If groundwater is present at 2-5m below ground level a sample of soil should also be taken from just above the groundwater table. Fewer sampling locations are thought to be necessary for samples at depth, as shown in Box 2.9. These recommendations apply to sites where pollution is not suspected. For sites where pollution is suspected the draft standard recommends that samples are taken from each suspect soil stratum and from the adjacent strata.

Multi-stage surveys

It may be beneficial in some situations to carry out an investigation of contamination in more than one stage. For example, the initial ground investigation may be followed by the preliminary design of reclamation proposals, and then by further ground investigations to clarify whether certain options are more acceptable than others. Similarly, where it is proposed that contaminated materials be removed, further investigation will be needed to define the quantities involved. However, first stage surveys involving very low sampling frequencies, provide little reliable information on the overall contamination status of a site.

A staged site investigation will have the advantage of focusing a contamination assessment on a particular area or areas of contaminated ground, but does have the disadvantage of being spread over a longer

Box 2.9: Recommended number of sampling locations on sites where contamination is not suspected[175]

Samples to 0.5m:	$n = 10 + 10A$
Samples from 0.5m to 2.0m:	$n = 3 + 3A$
Groundwater observation wells:	$n = 1 + 1A$

Where n is the number of sampling locations and A is the size of the site in hectares period of time. A focused investigation is likely to provide more accurate information about critical areas of a site and therefore be more cost effective. In addition the results of the first stage investigation will be useful to those people preparing preliminary programmes and budgets for reclamation work.

The hazardous waste site investigation programme of Baden Württemberg[115, 164] recommends three stages of site investigation after the initial historical research. A preliminary investigation, with limited costs, consists of initial systematic measurements and examinations of the site and resources at risk, using existing or easily established measuring and sampling locations and passive bio-monitoring of flora and fauna. This may be followed by a detailed investigation, designed to give a picture of the location, extent and quantity of contaminated materials. Further in-depth studies may then be carried out to assess options for clean up or containment of contamination. Between each level of investigation an evaluation is carried out to assess whether further investigations are necessary.

2.6.3 Sample collection

Solids

Methods of sample collection should endeavour to ensure that the sample taken is as representative as possible of the material being investigated. Bulking of samples from different depths or from different locations is not recommended as it is the range of values, in particular the maximum concentrations, rather than the average concentration, which is of relevance to risk. However, when sampling a particular material from a trial pit, several samples of the material may be taken at the same depth and these combined to produce a sample which is representative of the material at that location. In the laboratory samples should be sub-sampled by coning and quartering.

Mixing of samples in the laboratory to reduce the number of analyses which have to be carried out is suggested in the Dutch draft standard for exploratory investigations.[175] Samples which differ in visual appearance or by smell should not be mixed together. It is also preferable for mixed samples to be made up of neighbouring samples from the same depth. Portions of the original, separate samples should always be retained in case required for further analysis.

Samples from trial pits are taken either from the sides of the pit or from the material held in the bucket of the excavator. The former method is preferred as the place from which the sample has been taken can be more accurately defined. Any surface dusting of material from other parts of the trial pit should be removed before sampling. A long-handled tool should be used for sampling from the sides of the trial pit at depth in circumstances where it is inadvisable for the investigator to enter the trial pit.

When taking samples from the bucket of the excavator care should be taken to avoid materials which have fallen into the bucket from the sides of the trial pit as this may mislead the investigator as to the depths at which contamination occurs. If possible samples should be obtained from the centre of large lumps of material.

The method of sampling used should be recorded in the log for each trial pit. Sampling tools should be made of stainless steel and be easy to clean between each sample.

The volume of sample required will vary with the analysis required but one litre is generally sufficient. Containers should be made of materials which do not react with the sample, or allow escape of substances present in the sample. Thus, polyethylene and many other plastics should not be used where organic contamination is suspected, but are acceptable when carrying out analysis for metal contaminants only. Glass containers should be used when organic contamination is suspected.

Sample containers should be robust and air-tight on closure, with large openings to enable easy filling and emptying. Samples should be clearly labelled, with site name, date, sample location and depth.

Liquids

Samples of liquids found in trial pits may be obtained by a variety of methods, such as lowering a container into the pit. Samples may be obtained from standpipes installed in boreholes and backfilled trial pits by use of a bailer or various hand or mechanical pumping techniques. A period of at least several days should elapse between installation of such standpipes and collection of samples, to allow equilibrium of water in the standpipe with surrounding groundwater.

Containers for liquids should not react with sample constituents, or allow substances to escape. Thus glass bottles with PTFE seals should be used where volatile organic compounds are suspected. Plastic bottles will be suitable when it is known that the analysis of organic compounds will not be required. Containers should be rinsed several times with the liquid being sampled before filling and sealing. Liquid samples are far more likely than solid samples to undergo change after collection, for example by reactions between substances in solution, precipitation and dissolution and adherence to container walls. The storage of samples at low temperature is recommended to arrest chemical and biological activity in the sample. Various chemicals can also be added to preserve particular substances. For example, acids can prevent the precipitation of metals, and sodium hydroxide can prevent breakdown of cyanides. When taking water samples, particularly when low concentrations of contaminants are of interest, a selection of different bottles, each containing different preservatives, may be required. The analysis suite required should therefore be known in advance of taking liquid samples.

2.6.4 Analysis

Analysis of the samples after collection is often the most expensive part of investigations into contamination of land. Careful thought has to be employed in deciding which samples to analyse and for what constituents. Information obtained in the desk study is likely to be of great value in this respect. The marginal costs of sample collection are small, and so it is advisable to collect a large number of samples, and then analyse only a selection of these. Analysis of further samples can be carried out later in the light of initial results. Samples should always be kept until the reclamation proposals have been finalised, in case further analysis is required.

The analysis suite should be chosen on the basis of:

- the substances which are thought likely to be present, on the basis of the past uses indicated by the desk study;
- the substances which are thought likely to cause a hazard, given the proposed use of the site.

Measurement of pH, a basic parameter of soil and water conditions, should be carried out in nearly all site and soil investigation situations. It is inexpensive and is a good general indicator of site and soil conditions. Screening analyses, which indicate the presence of a group of substances but not the concentration of individual compounds, can be used to gain maximum information for minimal analysis expenditure. Further analysis is often then required to identify the particular substances present, but this can be directed at samples shown by the screening analysis to contain high concentrations of the class of compound in question. For example, analysis for total sulphur can be followed by analysis for total sulphate, sulphide and elemental sulphur, and then subsequently water-soluble sulphate if total sulphate concentrations are unusually high. Similarly, analysis for total cyanides can be followed by analysis for free cyanide and thiocyanate. Measurement of electrical conductivity gives an indication of the concentration of soluble ions and samples with high conductivity should be followed by analysis for cations and anions.

Analysis for organic compounds is particularly complex and can be expensive. An initial screen by solvent extraction and gravimetric determination is often carried out, but these methods generally do not measure volatile compounds, as these are lost during evaporation of the solvent. Analysis of the head space, *i.e.* the space at the top of the sample container, for volatile compounds is a more appropriate screening technique for this type of contamination. For example, a flame ionisation detector, which measures total flammable hydrocarbons, can be inserted into the air space in the sample container. Techniques such as thin layer chromatography can be used to separate organic compounds into different types of compounds, but the identification of individual compounds generally requires techniques such as gas chromatography (GC) or high performance liquid chromatography (HPLC), often involving lengthy extractions and run times.

There are standard methods of analysis for many substances, but not for all those likely to be present in contaminated land at coal and steel sites. It is important that the person specifying the analysis suite and interpreting the results has a good understanding of the methods used, their advantages and limitations. Good communication with those carrying out the analysis is essential. In particular, when reporting results laboratories should give sufficient information about the methods used and how they have been reported to enable a correct interpretation to be made.

Generally the errors introduced in the sampling process, in terms of the samples being representative of the material in question, are much greater than those at the analytical stage. It is thus often better to analyse a large number of samples by a reasonably accurate method than a small number by a very accurate and costly one. However, for groundwater samples in particular, very low concentrations of contaminants may be of interest.

The limit of detection of the analytical method employed should therefore always be lower than the lowest concentration which could be of concern.

Analysis should be subject to rigorous quality control procedures to ensure that samples are not lost, correct analytical procedures are carried out and results are reported correctly. Standard reference materials *i.e.* materials as similar as possible to those being analysed but containing a known concentration of the analyte, should be used to verify analytical procedures. A reliable laboratory may be chosen on the basis of its membership of an accreditation scheme which conforms to the European standard for the competence of calibration and testing laboratories, EN 45001.

2.6.5 Interpretation of results

Results of analysis must be interpreted to make an assessment of the contamination status of a site. This requires decisions to be made on what concentrations are to be regarded as signifying contamination. There are three different approaches to this problem:

- comparison with 'natural' concentrations in unpolluted soils;
- comparison with concentrations in surrounding soil;
- consideration of the risks associated with the presence of the substance at different concentrations.

These approaches may be applied to individual sites, on a case by case basis, or they may be used to derive standards for soil concentrations of individual substances which are then used when assessing large numbers of sites.

Whilst any increase in soil concentrations of hazardous substances above 'natural' levels may be considered to be undesirable, in practice, comparison of soils from heavily industrialised urban areas, where the majority of land contains elevated concentrations of potentially hazardous substances, with concentrations found in soils of unpolluted rural situations would lead to unjustified alarm and misdirection of resources.

Comparison with local background soil concentrations is a more practical approach, which allows areas containing high concentrations of contaminants to be identified and resources directed at treatment of these, to give a gradual improvement in the contamination status of an area over time.[118] This approach of developing standards specific to a local area is also necessary where the background concentrations are naturally high, for example in the south-west of England where arsenic concentrations in soils may naturally be as high as several hundred mg/kg.

The third type of approach considers the risks associated with the presence of the substance in question and attempts to define concentration values below which the risk is negligible, and above which the risk is unacceptable. Evaluation of risk implies consideration of the system:

$$\text{Contaminant} \xRightarrow{\text{Route}} \text{Target}$$

In this model the target may be people, animals, plants, water resources or building materials.

Routes by which people may be exposed to contaminants include:

- direct skin contact;
- inhalation of dust or gases;
- ingestion, directly or via food or drinking water.

The degree to which routes of exposure operate depend, amongst other considerations, on the use of the site. Therefore, the risk assessment approach frequently takes into consideration the intended use. Assessment of risks to humans and animals from toxic substances in soils involves determining acceptable dose levels from toxicity data and then relating soil concentrations to dose levels by consideration of exposure routes. A large degree of uncertainty is involved in this assessment, due to the paucity of toxicity data, especially for chronic exposure to low levels of toxic substances, and the many unknowns affecting the routes of exposure.

Approaches to the interpretation of soil concentrations in the Netherlands, Germany and the United Kingdom are discussed here.

Dutch approach

In the Netherlands the Interim Soil Clean-up Act of 1983, introduced the Soil Clean-up Guideline,[227] which contains the most widely used set of concentration values for assessment of contaminated sites. The 'Dutch List', as it is known, consists of three sets of concentration values for a wide range of substances in soil and groundwater. The three types of value are explained in Box 2.10.

The principle of the Dutch approach is that contaminated soils should be restored to 'multifunctionality' *i.e.* the soil should be suitable for a wide range of possible future uses, such as crop production, grazing, groundwater recovery, ecological functions, and construction or development.[41] This principle can however be relaxed when

Box 2.10: Dutch Soil Clean-up Guideline values for soil concentrations

The 'Dutch List' as it is known, consists of three levels of concentration values set for a range of substances in soil and groundwater. The three levels have the following significance:

- A-value — based on average background concentrations, implying unpolluted soils
- B-value — implies pollution present and further investigation is required
- C-value — implies significant pollution present and clean-up required

environmental, technical or financial circumstances make remediation impossible in practice. Where multifunctionality of soils is not restored, any hazardous effects must be controlled by isolation of the site with control and monitoring procedures to ensure the effectiveness of the isolation system. A soil is considered to be multifunctional if it conforms to the A-values of the Dutch List. These values were originally defined by reference to average concentrations of unpolluted soils. However, in 1987, in the Environmental Program 1988-1991, the Dutch Government published a provisional list of reference values for acceptable soil quality, revising many of the original A-values.[248] They are an attempt to define 'no-effect' levels of substances in soils. The preparation of the reference values considered standards set in other policy areas, such as standards for drinking water, surface water and food. In setting standards for metals and fluoride concentrations, 'clean' rural areas were considered, and modelling of soil solution/solid phase relationships and toxicological risk assessment was carried out for organic compounds. Because the bioavailability of substances is dependent on soil type the values are given as formulae which derive soil concentration from clay and organic matter content of the soil.

The 1983 Interim Soil Clean-up Act is to be incorporated into the Soil Protection Act 1987.[227] This Act provides for a wider policy on prevention of soil pollution. The Soil Clean-up Guideline is to be revised and renamed the Guideline for Soil Protection. This will contain the revised A-, or reference values and revised C-values, but no B-values. The new C-values which are to be renamed 'intervention values', have been set at the level thought to represent a serious threat to Man and the environment. The derivation of these values is described in Box 2.11. The presence of contaminants at concentrations which exceed the C-values indicates a need for clean-up, in that there is a potential serious threat to Man or the environment. However, the new Guideline for Soil Protection recognises that further investigation is needed to determine actual threat and therefore whether or not clean up should have a high priority. This involves assessment of the extent of actual exposure, which is primarily determined by soil use.[29]

Box 2.11: Derivation of Dutch C or 'intervention values'[29]

Separate values were initially derived for the two aspects, Man and the environment.

(i) A "serious threat to the environment" was taken to be "irreversible and irreparable damage to the species composition", defined as when fifty per cent of the species present experience adverse effects as a result of the concentration of one or more contaminants. C- values were then derived following a search of ecotoxicological data for plants, soil fauna and micro-organisms.

(ii) Soil concentrations constituting a "serious threat to Man" were derived from consideration of carcinogenicity/toxicity data and exposure pathways. The carcinogenicity/toxicity data were used to set maximum tolerable risk (MTR) levels equivalent to the maximum daily intake of a compound which can be taken orally without experiencing adverse effects on health, or the quantity of a carcinogen which corresponds to a risk of one additional case of a lethal tumour in 10,000 lifelong exposed individuals. The soil concentration which could lead to a dose equivalent to the MTR was then calculated from consideration of exposure pathways.

The lowest of the two C-values (one for ecotoxicology and the other for human-toxicology) was chosen as the new soil C-value, provided the uncertainty attached to this C-value was not much greater than that of the other C-value. Soil C-values were then corrected for organic matter content and clay content, factors which influence bioavailability, using the formula derived for the reference A-values.

Groundwater C-values were calculated by reference to the soil C-values using soil-water partition coefficients and assuming an equilibrium between soil and water partitioning. Because of the uncertainties involved in this process the values obtained were then decreased by a factor of 10.

German approach

In Germany policy on contaminated land is the responsibility of the Länder although a federal law on soil protection is in preparation. Several studies have been carried out on soil concentrations in specific areas to determine regional background levels which are then used for assessment of contaminated land. Risk assessment procedures are also used for individual sites and to produce soil standards, such as those of Eikmann and Kloke.[139] These were published in a communication of the VDLUFA (the German association of agricultural research institutes) and are to be made legally binding in Saxony. The publication gives reference levels for hazardous substances in soils. Three concentration ranges are given:

- **A**: safe range, concentrations found in natural, unpolluted soils;
- **B**: tolerable range, concentrations which, on the basis of present knowledge, do not cause damage to people, animals, plants, or the soil ecological functions;
- **C**: toxic range, concentrations which cause discernable damage to people, animals, plants and the ecosystem. Clean up, or prevention of contact with contaminated soil is considered urgent.

These three ranges are divided by two soil values:

- BWI: between A and B ranges, it does not vary with site use;
- BWIII: between B and C ranges, varies with site use.

Additionally, within the B range there is another soil value, BWII, which signifies a contaminant concentration at which consideration should be given to clean up or changing the use of the area within an appropriate timescale, though any risks are not acute. The interval between BWII and BWIII represents a safety range where clean-up is to be considered but is not urgent.

Values have been set for BWI, BWII and BWIII for a wide range of metals, benzo-a-pyrene (a polyaromatic hydrocarbon), PCBs, furans and dioxins, for various urban and agricultural uses. These include children's play areas, domestic gardens and allotments, sports and playing fields, parks and recreational areas, industrial and commercial areas, with and without impermeable ground cover, agricultural areas, and non-agricultural ecosystems. For each type of use the target group which is to be given protection (*e.g.* children, people of employment age, groundwater or plants), the assumed route of uptake, the soil area and soil depth is given. Soil areas to which the BW values apply are generally those that do not have a good vegetation cover. The depth of concern varies between 0.1 and 0.5m for the various uses.

Guidance on the assessment of the aggressiveness of soils towards building materials is provided in the German standards, DIN 4030 (June 1991) "Evaluation of liquids, solids and gases aggressive to concrete" and DIN 50929 (September 1985), "Probability of corrosion of metallic materials when subject to corrosion from the outside".

UK approach

In the UK 'threshold' and 'action' trigger values have been published for a limited range of substances for various types of end-uses including, in order of decreasing sensitivity: domestic gardens and allotments; parks, playing fields, open space; landscaped areas, buildings and hardcover.[121] In this system there are two types of trigger concentrations. The 'threshold trigger' concentration is the concentration below which the risks are considered to be negligible and the site may be regarded as uncontaminated. The action trigger concentration is the concentration above which some form of remedial action is essential. At concentrations between these two values professional judgement is required to evaluate the need for treatment. 'Action' trigger concentrations for metals have not been specified except for reclamation of former metalliferous mine sites to pasture and grazing which is the subject of a separate document.[122] Trigger values are intended to be used to assess the suitability of a proposed new use of the land, not whether an existing use should be allowed to continue.

More specific guidance on the reclamation of particular types of site is published occasionally by the UK Department of the Environment. This guidance includes that for coal carbonisation sites.[86]

Information on acidity levels and sulphate concentrations which affect concrete is given in Building Research Establishment Digest 363, "Sulphate and acid resistance of concrete in the ground" (July 1991).

2.7 Assessment of industrial archaeological value

The assessment of former coal and steel sites should include an assessment of the possible historical and archaeological nature of a site and its various features. A specialist industrial archaeological input should preferably be sought on all projects (see Section 4.7).

A key task for the specialist is to establish the overall significance of the site *i.e.* whether it is of local, regional, national or even international importance. This will allow rational judgements to be made on the emphasis to give to conservation. Assessment of the industrial archaeological value of a site needs to examine criteria such as scarcity, representativeness, scientific interest, engineering interest, state of preservation and completeness. The amenity recreation/tourism implications also need to be considered.

Many EC countries are now drawing up a 'monuments protection programme' on an industry-by-industry basis; iron and steel sites for example are classified in order of interest and specific site features may be listed for preservation. Such programmes will greatly aid the assessment of sites. Official lists such as any national archaeological record database, lists of scheduled ancient monuments, and regional archaeological sites and monuments records should be examined to see whether they include any features on the site. Specialists, volunteer groups and societies often maintain valuable databanks with lists of important features and they may also have published "standards for the survey and recording" of such sites. In the USA there is a standard "Guidelines for Inventories of Historic Buildings and Engineering and Industrial Structures" when work is carried out at three levels:

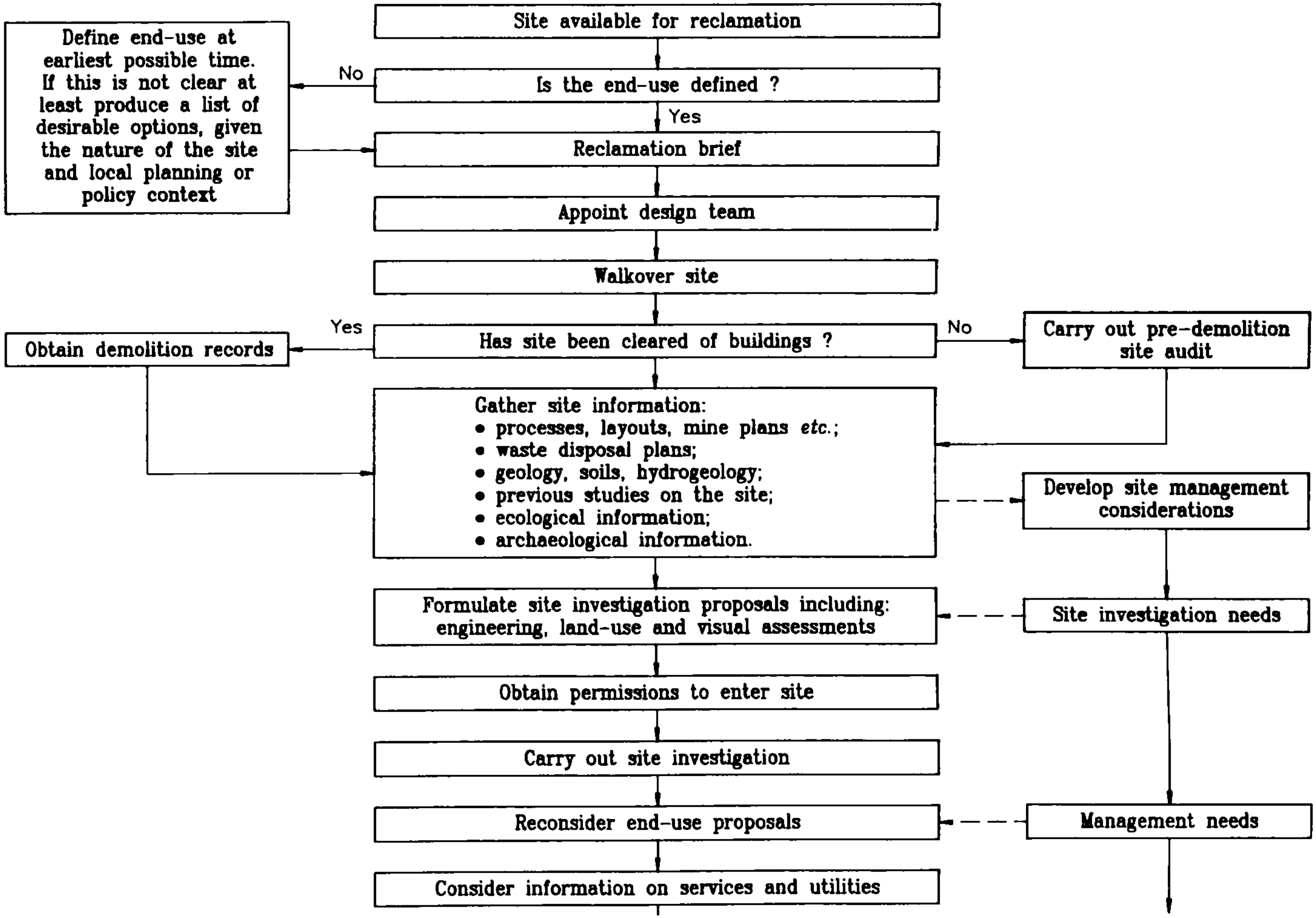
- Level I: file search, written overview and bibliography;
- Level II: reconnaissance survey to given standards;
- Level III: intensive survey with simultaneous recording and evaluation.

Levels I and II can often be carried out by voluntary groups but Level III is usually done by contractors. All sites should be studied to Level I, the more historically interesting sites to Level II and III.

2.8 Reclamation proposals

The final stage in the site assessment process brings together all the different issues which have been covered in the investigation phase and puts forward initial proposals for reclamation. At this stage decisions between any conflicting objectives will have to be made to produce the most effective solution for the site and to allow detailed design of a reclamation scheme to proceed. The design of treatment and amelioration measures is discussed in Chapters 11, 13 and 14. Chapter 16 places site investigation and reclamation in the wider context of planning, funding and local support, illustrating the need for an integration of good design, public acceptability and clear objectives in the fulfilment of a successful scheme.

The relationship between the activities carried out during site assessment and those concerned with the reclamation and management of former coal and steel sites is shown in Figure 2.5, which is a flow chart of the principal stages involved.


Site available for reclamation
Is the end-use defined ?
No
Yes
Define end-use at earliest possible time. If this is not clear at least produce a list of desirable options, given the nature of the site and local planning or policy context
Reclamation brief
Appoint design team
Walkover site
Has site been cleared of buildings ?
Yes
No
Obtain demolition records
Carry out pre-demolition site audit
Gather site information:
• processes, layouts, mine plans etc.;
• waste disposal plans;
• geology, soils, hydrogeology;
• previous studies on the site;
• ecological information;
• archaeological information.
Develop site management considerations
Formulate site investigation proposals including: engineering, land-use and visual assessments
Site investigation needs
Obtain permissions to enter site
Carry out site investigation
Reconsider end-use proposals
Management needs
Consider information on services and utilities

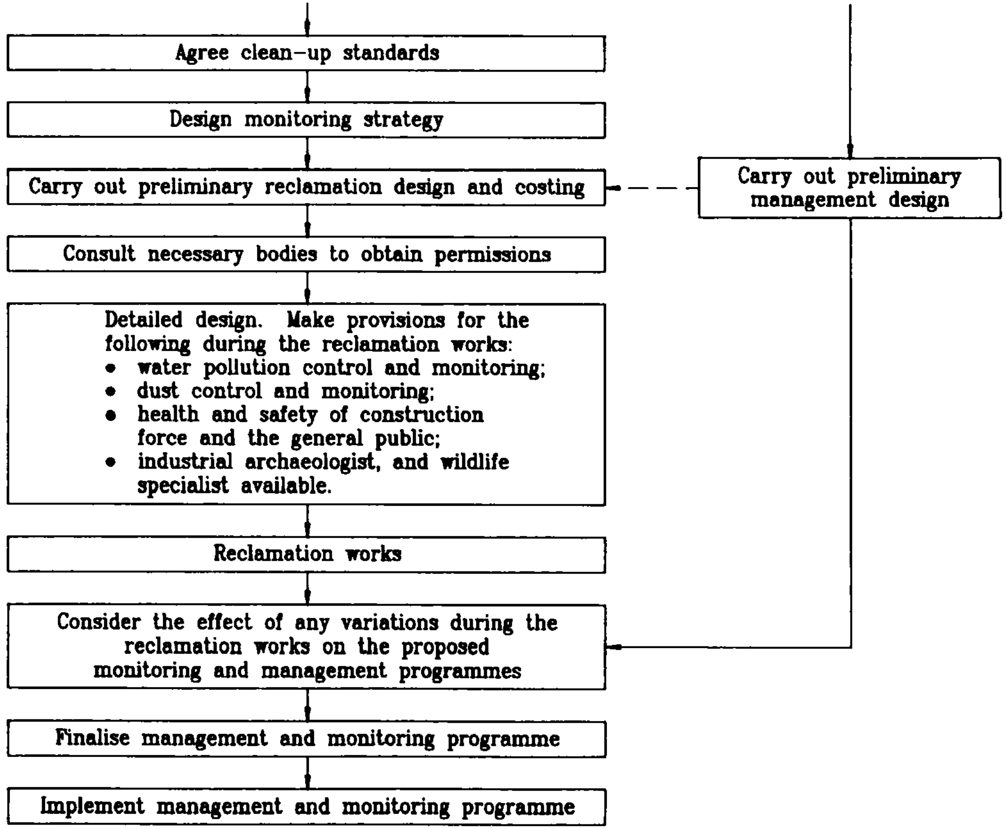


Figure 2.5: Flow chart of the principal stages in the investigation, reclamation and management of a former coal or steel site