EA WASTE MANAGEMENT

Waste Management Paper 26E

LANDFILL RESTORATION AND POST CLOSURE MANAGEMENT

Consultation Draft
August 1996

ENVIRONMENT AGENCY

WMP 26E

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(Revised from April 1996)

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Landfill Restoration and Post-Closure Management

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Foreword

Purpose and Readership

This Waste Management Paper (this paper) provides guidance on the

- **restoration**
- **aftercare**
- **post-closure management**

of landfill sites.

It includes restoration and aftercare design objectives and opportunities, restoration and aftercare to agriculture, woodland, nature conservation and hard end uses, and the long term management of both established vegetation and engineering systems.

It forms part of the Waste Management Paper 26 (WMP 26) series which updates and replaces WMP 26 (1986). The series comprises

WMP 26A	Landfill Completion (published)
WMP 26B	Landfill Design, Construction and Operational Practice
WMP 26D	Landfill Monitoring (in preparation 1996)
WMP 26E	Landfill Restoration and Post-Closure Management
WMP 26F	Landfill Co-disposal (in preparation 1996)

In planning the restoration and aftercare of new or existing landfill sites, the reader should have particular regard to the interface with operational design, construction and practice, and should consult both WMP 26B and WMP 26E. For guidance on the specific aspects of landfill completion, monitoring and co-disposal, WMPs 26A, D and F respectively should be consulted. Waste management licensing is addressed in WMP 4.

Aims

The ***overall aims*** of this Waste Management Paper are:

- **To provide guidance to practitioners on design, restoration and aftercare of landfill sites.**

- **To assist in improving standards of landfill restoration and aftercare in the UK in accordance with good practice.**

- **To identify and promote ways of making restoration and aftercare more cost-effective, thereby ensuring most efficient use of resources.**

- **To make restoration and aftercare of landfills in the UK environmentally sound and operationally practical.**

- **To assist in making landfill a sustainable and publicly acceptable means of waste disposal through restoration practice and aftercare techniques. This requires commitment to high standards of restoration, and realistic landfill economics.**

Contents

This paper has 14 chapters, a set of appendices, a glossary and a bibliography for further reference and guidance. The paper is arranged in four main parts as follows:

Part 1 (Chapters 1, 2 and 3) explains the background, concepts, issues and legislative framework for landfill restoration and aftercare.

Part 2 (Chapters 4 to 7) concentrates on the planning, assessment and design processes which precede any on-site restoration and aftercare work.

Part 3 (Chapters 8 to 12) provides technical and practical advice on soil issues, and restoration and aftercare to a range of after-uses.

Part 4 (Chapters 13 and 14) gives information and advice on the long term maintenance of both vegetation and the environmental protection systems during the aftercare period and beyond.

Acknowledgements

The paper sometimes refers to registered names and trademarks. The Agency recognises the owners' rights to these names and trademarks.

Chapter 1

Introduction

General principles

1.1 The WMP 26 series encourages

- a *holistic* approach to landfill: holistic implies that the process should be integrated from initial concept to final capping, restoration and aftercare

- the use of scientific and engineering skills in landfill design, operation and restoration

- site specific *risk assessment*, rather than a prescriptive, approach to environmental protection. The risk assessment indicates the design, operational and restoration practices appropriate to each landfill site.

1.2 The site operator and designer must consider the restoration and aftercare of the landfill throughout the life of the site, from the initial stages to physical stabilisation and statutory completion.

Readership of the paper

1.3 The paper is intended for use by skilled practitioners, waste regulators, planners, statutory authorities, and landfill designers and operators.

1.4 It is being issued in the waste management series, which is primarily aimed at waste regulators and the waste management industries. However, this paper is concerned with activities and issues which are relevant to the land use planning controls over landfills as well as to waste management licensing. It is intended to promote good interaction and interface between these two sets of controls by both industry and regulators.

1.5 Certain chapters may be of more direct interest to regulators or practitioners and have been written with that readership in mind.

- For example, the chapters on design are written primarily for the designer, and the chapters giving practical, technical advice on restoration and aftercare site works for the operator and his contractors. However, these chapters will be more useful if the reader takes them in the context of the paper as a whole.

Scope of the paper

1.6 This paper covers the restoration and aftercare of

- new and existing land*fill* sites i.e. a quarry or other similar void filled to surrounding ground level
- new and existing land*raising* sites i.e. an area filled to form a new raised landform which may be considerably higher than the surrounding land
- sites which have accepted all types of wastes including special, household, commercial, industrial, demolition/construction and inert wastes.

1.7 This paper

- describes the restoration and aftercare planning and design stages at the start of the landfill scheme
- gives guidance on the integration of the restoration design with operational and pollution control priorities
- reviews relevant legislation and policy
- discusses technical considerations and professional skills
- considers post-closure management of engineering systems
- considers ways of minimising the impact of these works on aftercare and after-use.

1.8 This paper deals only with the restoration and post-closure management of landfill sites and is not intended to address contaminated land issues which are covered by section 57 of the Environment Act 1995. Separate guidance is available on remediation and reclamation of contaminated land sites.

Definitions

1.9 Practitioners and regulators may apply different meanings to commonly used terms, such as restoration and aftercare. The paper uses key terms as follows:

Restoration. The process that returns a landfill site to a condition suitable for its after-use. Restoration includes design, initial landscaping works, soil spreading and after care.

Aftercare. Work done after replacement of the full soil profile to bring the land up to the required standard for the after-use, comprising cultivating, fertilising, planting, draining and otherwise treating the land;

After-use. The intended use of the restored land.

Post-closure management. Works done to maintain pollution control systems and monitor their effectiveness during the post-closure period.

The need for new guidance

1.10 The Department of Environment last published guidance on landfill restoration in 1986 (WMP 26)[1]. Significant developments since then have led to the need for revised guidance.

Public opinion

- There is increasing public awareness of the importance of successful, sustainable restoration, and aftercare and increased interest in the choice of after-uses being proposed.

Changes in farming practice

- Changing agricultural economics are encouraging planners and operators to consider a wider range of potential after-uses for landfill sites with a gradual trend away from pasture agriculture.

Research findings

- Recent research results (on accelerated stabilisation, assessment of stability and estimation of settlement, and on the processes and products of biodegradation) have major implications for the design and practice of landfill restoration[2].

- Continuing research on tree planting on landfill sites suggests that the guidance contained in WMP 26 should be reviewed[3].

New landfill technologies

- New technologies (for landfill construction and capping, landfill gas management and leachate management) affect the timing of, and techniques for, landfill restoration.

New design technologies

- Advances in computer aided design programmes for landform and landscape design, and calculation and manipulation of landfill volume, have introduced an important technology into restoration design.

New legislation and guidance

- The legislative framework for waste management planning, control and regulation has been extensively revised.

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[1] WMP26 Landfilling Wastes, HMSO 1986.
[2] WMP26F Landfill Co-Disposal, HMSO 1994.
[3] The Potential for Woodland Establishment on Landfill Sites, M C Dobson & A J Moffat, Forestry Authority (for DOE), HMSO.

Chapter 2

Concepts and issues

Introduction

2.1 This chapter

- outlines the landfill process: see paragraph 2.2 and figure 2.1
- summarises the key concepts in landfill restoration: see paragraphs 2.3 to 2.24
- discusses how landfill engineering affects restoration and aftercare: see paragraphs 2.25 to 2.34
- considers essential issues in restoration and aftercare: see paragraphs 2.35 to 2.53.

The landfill process

2.2 Figure 2.1 exhibits the stages of the landfill process and keys them to the Waste Management Papers.

Key concepts in landfill restoration

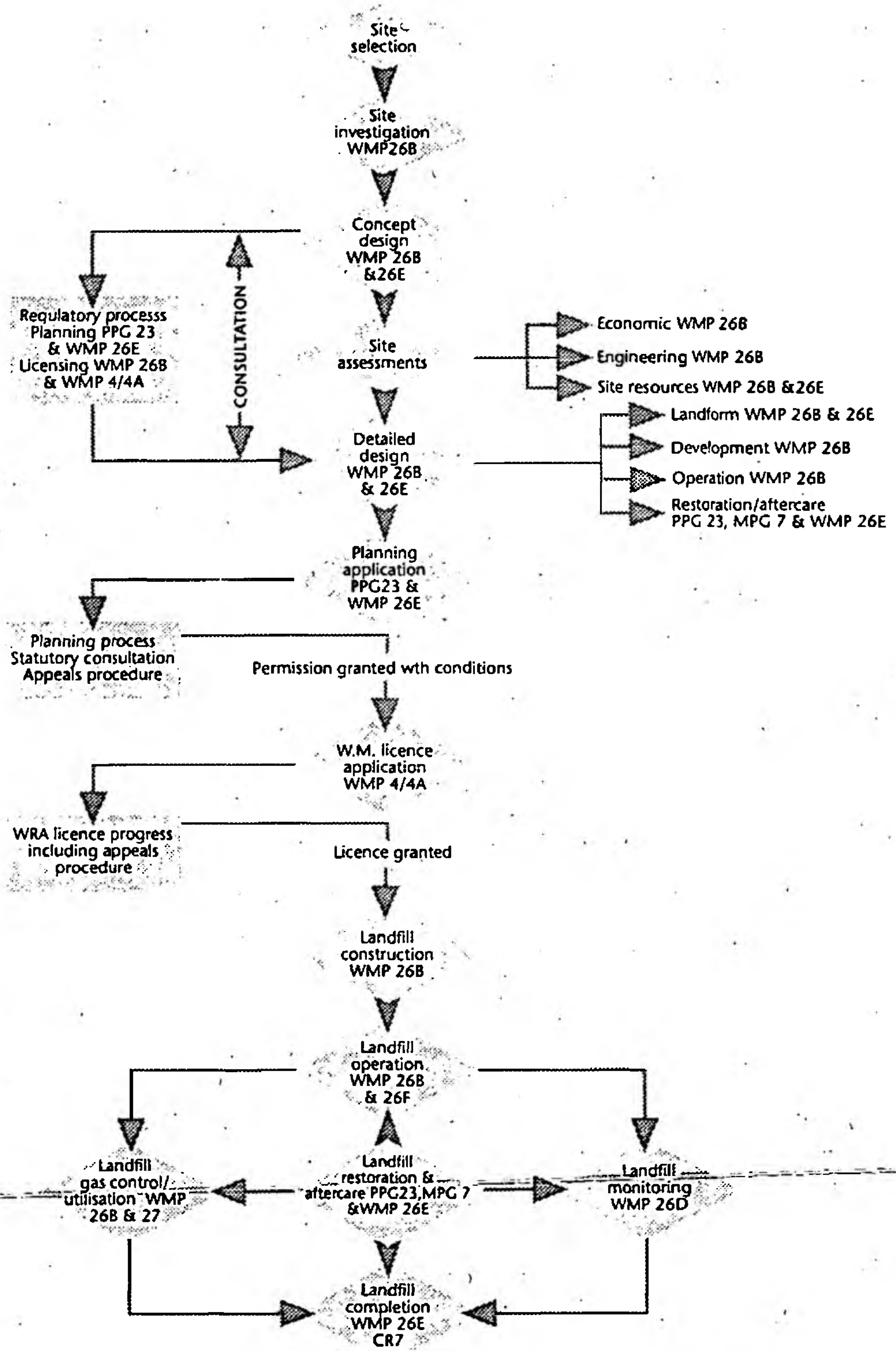
2.3 Paragraphs 2.4 to 2.24 describe six key concepts in landfill reclamation.

Holistic design

Concept 1: Restoration and aftercare are an integral part of the landfill process.

2.4 Landfill is a complex process. Like all complex processes, the easiest model proceeds in discrete stages: design, development, operations, environmental control, restoration, aftercare and post-closure management. The overall framework is set by the conditions of the planning permission and the waste management licence. Within this framework the landfill designer must see landfill as a **continuing process.** His design must enable the operator to **integrate** landfill operations, environmental control and restoration.

Figure 2.1 The landfill process



2.5 The practitioner must recognise that a design which is ideal for operations may conflict with what best suits environmental protection, and that either or both of these will not wholly match the demands of restoration. He should ensure that the objectives and potential conflicts are explicit in order that the designer can reconcile them, so as to produce an integrated design. Chapter 6 looks at the design process.

2.6 The initial programme of works to instal the cap and the environmental control systems, and to carry out restoration and aftercare should

- be drawn up at the start of the scheme
- be *flexible* enough to take account of
  - ► new technologies
  - ► changes to the rate of landfilling
  - ► other alterations to the original programme.

Site specific restoration based on risk assessment

Concept 2: The restoration plan should be site specific: it must suit the site and its environmental setting.

2.7 This concept must be applied to the design of all landfills. It will influence

- ► landform and slope stability: see paragraph 2.8
- ► surface water run-off and erosion: see paragraph 2.9
- ► restoration activities that may affect environmental protection systems: see paragraphs 2.10 and 2.11.

i Landform and slope stability

2.8 The landform design must take account of

- ► landscape integration, visual impact and after-use
- ► waste types
- ► gradients for slope stability
- ► the potential for soil slip, especially if a membrane capping system is to be used (see Chapter 6, particularly paragraphs 6.34 and 6.80 - 6.83).

ii Surface water run-off and erosion

2.9 Effective control of run-off and erosion depends on the slope gradients. Other associated factors include

- drainage design
- cut off ditches and underdrainage (see Chapter 9)
- timing of cultivation and vegetation establishment (see Chapters 7 and 8).

iii Restoration activities which affect environmental protection systems

2.10 Restoration entails activities that may improve the performance of environmental protection systems. It can thus reduce environmental risk. In particular

- drainage installed directly over the cap diverts water percolating through the soil. This reduces waterlogging and water ingress through the cap (see Chapter 9)
- gradients may be designed to encourage lateral drainage and run-off. This reduces the amount of rainfall arriving at the cap (see Chapter 6)
- soil depth and type will control the rate of infiltration and downward drainage of rainfall, especially in clayey or poorly structured restored soils (see Chapter 8 and Appendix B)
- established vegetation reduces rainwater infiltration through the profile. It does this by
    - intercepting rainfall on the leaves
    - taking moisture out of the soil during spring, summer and autumn for growth.

The combined mechanism is termed evapotranspiration (see Appendix B).

2.11 The operator must be able to operate, maintain and monitor the gas and leachate control systems at design efficiency throughout their planned life. Restoration must be designed and programmed so as to make this straightforward and cost effective.

Cost effective reclamation

Concept 3: Restoration must be cost-effective

2.12 The principles of cost effectiveness in landfill reclamation are to

- relate the choice of after-use to the available restoration materials
- design environmental protection and reclamation works together to minimise future conflicts and abortive work

- allow realistically for the cost of reclamation works in the initial economic appraisal of the site

- consider the needs of reclamation throughout the operational life of the site.

2.13 The promoter of a new landfill must convince the planning authority and the waste regulatory body that he can fund restoration, aftercare and post-closure management.

2.14 A wider choice of after-uses and better restoration techniques improve the likelihood of the operator making his restoration and aftercare both cost-effective and technically successful. Agriculture and some amenity after-uses require both topsoil and subsoil, but topsoil is not necessary for after-uses such as tree planting and nature conservation.

2.15 Wherever possible these materials should be derived from on-site soils. If these are no longer present careful selection of both natural geological materials and incoming wastes should be made. The choice of an after-use which does not need topsoil will also be a cost-effective and appropriate solution.

2.16 Careful programming

- prevents conflicts between environmental control works and restoration works

- avoids extensive re-instatement of restored areas

- increases the cost effectiveness of restoration and aftercare.

Restoration working plan

Concept 4: The restoration strategy includes a comprehensive plan of restoration and aftercare works. The plan forms part of the site manual.

2.17 The operator should include the detailed restoration strategy in the site manual. This will ensure that the design objectives and information are transferred from the design team to the project team who, years or decades later, will implement environmental protection, restoration and aftercare. This is described in more detail in Chapter 7.

Restoration as a developing process

Concept 5: Restoration is a developing process that responds to operational needs and site conditions.

2.18 Landfill restoration works continue throughout the life of the site. Their character and timing depend on the progress of landfill operations.

2.19 Thus, restoration works include

- *initial restoration* - landscaping around the perimeter of the site to screen it and to improve its external appearance, landscaping around the site entrance

- *soil stripping and storage* in advance of site development and filling

- *temporary greening* - establishing vegetation on

    - ► areas that, although within the operational part of the site, will not be required for landfilling for some time

    - ► areas whose appearance must be improved because they are visible from outside the site

    - ► areas where run-off and rainwater infiltration must be reduced.

- *interim restoration* - replacing of part of the final soil profile, then establishing a grass cover (see Chapters 6 and 7). This is beneficial on areas which may be affected by settlement, where remedial works to environmental protection measures (gas and leachate systems) will be needed: **interim restoration is particularly important on sites which are designed and operated for accelerated stabilisation**

- *final restoration and aftercare* - entails

    - ► replacing the full soil profile

    - ► establishing the after-use and the landscape features, for example trees, hedgerows, arable agriculture.

2.20 Table 2.1 shows the timing of restoration works in relation to site operations.

- ► Where the site is being landfilled and restored in phases, several restoration stages will be in progress simultaneously.

Table 2.1 The timing of restoration works in relation to site operations

Site operation	Restoration works
Preparation and development	Retain as much of existing site undisturbed, in non- landfill use as possible by controlling extent of initial preparation and development works. Soil stripping. Screening and perimeter landscaping. Entrance landscaping. Management of non-landfilled areas.
Landfilling	Protection of non-landfilled areas and restored areas from windblown litter. Progressive screening in advance of phased landfilling. Screening and recycling of suitable wastes to provide restoration materials. Temporary greening of areas not required for landfilling to improve appearance of site.
Installation/completion of environmental protection systems leachate recirculation (accelerated stabilisation)	Interim restoration following placement of capping layer. Reinstatement of disturbed areas of interim restoration following remedial works.Interim restoration following placement of capping layer. Reinstatement of disturbed areas of interim restoration following remedial works.
Post closure management	Final restoration and aftercare. Installation of drainage systems and fencing. Tree planting. Continuing maintenance of reclaimed land. Maintain access to structures for monitoring. Decommissioning of gas/leachate installations and restoration of redundant compounds.

Restoration to promote landfill

Concept 6: Good restoration schemes promote public acceptance of landfill, and demonstrate the operator's expertise and environmental awareness.

2.21 Good landfill restoration and aftercare influence the public favourably towards future landfill sites. The operator can

- mount public exhibitions of landfill proposals
- advertise restoration improvements with signs and information boards
- allow public access to restored areas (consistent with site safety).

2.22 Community involvement can be created and maintained by setting up a *liaison group* at the start of the scheme. This typically consists of local authority officers, residents' associations and other local interest groups. It should meet regularly throughout the life of the site. The liaison group should be asked what local people would like to see done with the site after landfilling has ceased. This can also be a constructive response to genuine local concern about the site.

2.23 This community involvement can continue into the aftercare period. Local interest groups and schools may be invited to plant trees and shrubs, build footpaths and undertake nature conservation works. Such involvement must be at the operator's discretion.

Landfill engineering and operational considerations

2.24 Several characteristics of landfill engineering and operations affect the design, timing and implementation of restoration and aftercare. They include

- type of waste
- phased landfilling
- pollution control systems
- accelerated stabilisation
- settlement.

Type of waste

2.25 The design of restoration and aftercare is dependent on the types of waste the landfill contains.

- Sites which have accepted inert, excavation, construction and demolition wastes can more easily be given complex profiles: they may therefore be designed with more variation in slope gradients than sites which have taken industrial, commercial or household wastes.

- Water features may be built over sites which have accepted non biodegradable wastes if the risk to groundwater, from water infiltration, is low.

- Water features should generally not be built over a capped landfill: they increase the risk of water ingress through the cap.

Phased landfilling

2.26 Most larger landfill sites will be operated and restored in phases. Phased restoration provides opportunities for

- advance planting and site screening
- reducing the area of site disturbed at any one time
- returning land to beneficial after-use at the earliest opportunity
- screening later phases with restored earlier phases
- testing the effectiveness of environmental control systems, restoration and aftercare while there is still time to make changes on later phases.

2.27 The restoration scheme should include the treatment or management of those parts of the site which are outside the operational area, or which will be included in later phases of landfilling. It should extend to

- protecting existing land uses and their access from disturbance by suitable screening
- careful siting of landfill access roads
- preventing run-off from disturbed areas.

2.28 The restoration scheme should also show clearly how the operator will protect restored areas from windblown litter and surface water run-off.

Pollution control systems

2.29 A modern landfill which has accepted putrescible wastes will have systems to control and monitor leachate and landfill gas. The surface or above-ground features of these systems may affect restoration and aftercare, so

- a major aim when designing and operating environmental control systems should be to minimise their adverse effects on the aftercare and after-use of the site

- restoration, aftercare and after-use proposals must be realistic. In particular they must allow for frequent access for monitoring and maintaining the pollution control systems throughout the post closure period.

Design solutions must minimise potential conflicts: see paragraph 2.5.

Accelerated stabilisation

2.30 The principles of sustainable development entail the accelerated stabilisation of the landfill. Stabilisation should be complete within a generation. Leachate recirculation promotes biodegradation, but may also affect the timing of restoration. Accelerated stabilisation may cause faster initial settlement and higher rates of landfill gas and leachate production[4].

2.31 Since accelerated stabilisation means more operational activity immediately after completion of landfilling, it may interfere with restoration and aftercare. On a site which has been engineered for accelerated stabilisation, restoration must develop in parallel with operational needs. The operator must use interim restoration techniques to minimise the effect on final restoration: see paragraphs 7.18 to 7.25.

Settlement

2.32 Any site which has accepted biodegradable wastes will settle as the waste decomposes. The settlement rate reduces significantly after the first 5 years, but settlement continues, gradually reducing with time, until the waste is stabilised. Settlement is less pronounced in sites which have taken non-biodegradable wastes.

2.33 On sites which will settle, both final and surcharge (or pre-settlement) contours should be put to the planning authority with the planning application. Surcharge contours, calculated from predicted settlement, indicate to the planning authority the amount of overtip that is essential to achieve the final landform[5].

2.34 Settlement most significantly affects pollution control systems, the capping layer and restoration during the first 2 to 5 years after landfilling has finished. Its effects may include

- settlement of horizontal pipework
- damage to vertical wells and pipe connections
- differential settlement under the capping layer, and hence
- localised waterlogging or poor drainage.

Many operators use interim restoration to minimise the impact of settlement upon final restoration and aftercare.

Essential issues in restoration and aftercare

After-use options and aftercare

2.35 Restoration and aftercare techniques have improved, and the public now expects higher standards of aftercare at landfill sites. Landfill operators and planning authorities have looked beyond agriculture to a wider range of after-uses for restored landfill sites.

[4] See WMP26B, Chapters 3, 6 and 9.
[5] See WMP26B, Chapter 6.

2.36 The operator continues to be responsible for the site throughout the post closure period[6]. This has implications for the choice of after-use.

2.37 The operator and the waste regulator must agree a balance between the long term operation of the environmental protection systems, and the after-use and aftercare works. This balance may be achieved through

- careful design of the environmental protection system
- realistic landscape and restoration design: see Chapter 6
- integrating the long term maintenance of the engineering system with that of the restored land: see Chapter 14.

2.38 The operator and the designer should consider the after-use options and take a provisional decision at the initial design stage. They may need to seek specialist advice: see Chapter 4. Restoration to agriculture has usually been the major, or sole, option. However, operators in some areas of the country now review a wider range of after-uses, including amenity, nature conservation and tree planting. This trend may

- make restoration more cost effective
- minimise conflicts between aftercare and the maintenance of engineering systems.

Tree planting on landfill sites

2.39 Recent research has re-examined tree planting on landfill sites. It indicates that trees may be planted on capped and uncapped landfills without compromising the effectiveness of the pollution control systems, providing those systems have been properly installed[7].

2.40 This means that, in principle, a more natural and varied landscape design is possible on all types of landfill site. The operator can design restoration and aftercare proposals that blend the site into the surrounding landscape, increasing the scope for after-uses: see Chapter 10.

2.41 The designer must take site specific factors into account such as

- waste types
- site surroundings
- soil availability
- proposed after-use

when considering tree planting proposals.

[6] See WMP4.
[7] The Potential for Woodland Establishment on Landfill Sites. M C Dobson and A J Moffatt Forestry Commission (for DOE), HMSO.

2.42 A site which has accepted biodegradable wastes will

- need a comprehensive gas control system
- be subject to settlement.

2.43 Extensive tree planting is not an appropriate design solution for capped sites that have accepted putrescible wastes. Tree planting may compromise the effectiveness of the gas control system. It may do so either by root action, or more probably by making it difficult to gain access for monitoring, maintenance and remedial works. Even so, shelter belts, copses and hedgerows should be planted to integrate the site into its surroundings.

2.44 The solution lies in the restoration design and programming of final restoration works. If the landfill is likely to settle or need gas control systems the designer should consider carefully the location and extent of tree planting. The operator should delay tree planting in the affected areas of the site until the landfill is more stable, but should continue with earlier tree planting in non-landfilled areas where possible.

2.45 Tree planting may be undertaken more extensively on a site that has taken predominantly inert, construction and demolition wastes where problems of settlement and gas control will be greatly reduced.

2.46 Tree planting may also be a suitable after-use on old sites where biodegradation is almost complete and settlement and gas production have virtually ceased.

Soil availability and handling

2.47 The designer must consider whether the site itself can supply enough soils suitable for restoration work, particularly if the site was formerly derelict and where landfilling is being used to generate income to restore the site.

2.48 The operator improves the likelihood of cost-effective restoration if he

- assesses all incoming wastes for their suitability as restoration material: see Chapter 8
- screens inert materials or composts.

2.49 Soils imported for restoration should come from an approved source, and quality control is essential.

2.50 The planned accumulation of soil reserves throughout the active life of the site will reduce the amount of soil to be imported to the site once landfilling is completed. Phasing of landfilling and restoration can also help by spreading the period of soil importation. Material accumulated for restoration should not be used as daily cover. It must be held in an area where it will not become contaminated with tipped or windblown wastes, until needed for restoration.

2.51 Soil stored on site should be managed[8] so as to minimise the damage which will almost inevitably be caused by earth moving equipment. On-site soils must be stripped, stored and replaced in sequence. This work should be agreed with the planners and waste regulators and written into the working plan.

2.52 The main practical problems the operator encounters after closure result mainly from impeded drainage and poor soil structure, themselves commonly the result of soil compaction. Compaction in turn results from

- ► using inappropriate machinery and techniques for soil spreading
- ► carrying out the work in unsuitable, wet weather.

The operator will recognise that the techniques required for soil spreading are the opposite of those used when laying a compacted mineral capping layer.

- He must take steps to prevent or relieve soil compaction (Chapter 8).

2.53 Planning permissions now typically include conditions to avoid soil compaction during restoration and aftercare. These are usually developed in consultation with MAFF and the Forestry Commission.

[8]See Appendix A Soils

Chapter 3

Legislative framework and related guidance

Introduction

3.1 This chapter

- outlines the national legislation and official guidance that affect the restoration, aftercare and post-closure management of landfill sites
- describes the local planning framework for the development of sites
- considers, in more detail, the roles of the local planning authority (LPA) and the waste regulatory body in controlling restoration and aftercare.

3.2 Table 3.1 lists the legislation and official guidance on landfill restoration and aftercare[9]. A synopsis of the most important points follows in paragraphs 3.3 to 3.27.

National planning legislation

Town and Country Planning Act 1990

3.3 The Town and Country Planning Act 1990 influences waste disposal in England and Wales through

- development plans which set out policies and general proposals for the development and use of land
- district local plans and waste local plans which apply the policies of the structure plan to particular areas of land
- the grant or refusal of planning permission.

3.4 In Scotland the planning system operates under the Town and Country Planning (Scotland) Act 1972, as amended. It provides for the inclusion of waste disposal policies in structure and local plans.

The Town and Country Planning (Assessment of Environmental Effects) Regulations (Amended 1990). The Environmental Assessment (Scotland) Regulations 1989.

3.5 Under these Regulations (which implement E.C. Directive 85/337) Environmental Assessments (EA) must be provided with projects which need planning consent and which are judged likely to have significant environmental effects.

3.6 The guidance[10] suggests that

[9] See also WMP 26B.

[10] See DOE Circular 15/88 (Welsh Office Circular 23/88, Scottish Office Circular 13/1988). More information is contained in Environmental Assessment: A guide to the Procedures.

- waste disposal sites with a capacity of 75,000 tonnes per annum or greater may well be candidates for EA

- sites at which special waste is to be received, and sites located in environmentally sensitive areas are also likely to require EA under the Regulations

- sites taking smaller tonnages of these wastes, and sites seeking to accept only inert wastes are unlikely to be candidates for EA.

The Directive is currently (1995) undergoing revision, and there will be further guidance consequent upon any changes.

3.7 Under these Regulations an assessment of the physical environment of the site is required. The scope of the assessment will depend on the likely environmental consequences of the development.

3.8 The Regulations also directly affect the work of the designer. Measures to mitigate the adverse effects of the proposal, which include landscape design, screening, restoration, and aftercare, must be designed in detail.

Planning and Compensation Act 1991

3.9 The Planning and Compensation Act 1991 empowers local planning authorities to impose a five year *`Aftercare Period'* at all sites where permission is given to deposit refuse or waste materials. This period begins after replacement of the full soil depth i.e. the completion of any restoration conditions.

3.10 The Act makes the development plan overriding. An application must be determined in accordance with the development plan unless material considerations indicate otherwise.

3.11 This Act provides substantially improved powers for local planning authorities to enforce planning control. The powers include

- serving a "breach of condition notice" where there is failure to comply with any planting condition or limitation

- serving a stop notice, which can have immediate effect where there are special reasons to justify it[11].

National environmental protection legislation

Environmental Protection Act 1990

3.12 Part II of the Environmental Protection Act 1990 (EPA 90) deals with waste on land.

[11] Further guidance on these powers, for England and Wales, is in PPG18 "Enforcing Planning Control" and in DOE Circular 21/91 (WO 76/91).
[12] See WMP 26A.

3.13 Under EPA 90 Section 35(3) the licence permitting waste disposal may include conditions which relate to the period after the operations (authorised by the licence) have ceased. Section 39 of the Act provides that the licence may only be surrendered, and a certificate of completion[12] issued, if the waste regulatory body is satisfied that the condition of the land is unlikely to cause pollution of the environment or harm to human health. The implication of this provision is that the licence holder may remain responsible for the site for a significant period after landfill operations have been completed.

Waste Management Licensing Regulations 1994

3.14 Under the Waste Management Licensing Regulations 1994 an application for a waste management licence should include assessment information similar to that required under planning legislation (see paragraphs 3.5 to 3.8). The waste regulatory body often asks an applicant to supply a restoration plan. This should show

- contours of the restored site
- phasing details
- final drainage
- the proposed after-use of the site
- the proposed planting scheme.

3.15 In the aftercare period the applicant must normally provide

- landfill gas control and monitoring
- leachate control and monitoring
- settlement monitoring and predictions
- maintenance of planting schemes, hardstandings and other elements of the restoration.

3.16 Under the Regulations the landfill licence continues in force until the waste regulatory body accepts its surrender. This may continue beyond the cessation of landfilling. The applicant must plan for this at the outset. He must show that he has arranged the funding of long term obligations, such as monitoring water and landfill gas.

The Environment Act 1995

3.17 The Act established an Environment Agency (England and Wales) and a Scottish Environment Agency (SEPA). The objectives of the Agencies are to enhance the environment, and to contribute towards achieving sustainable development. The Agencies have pollution control powers. The Environment Agency subsumes the present functions of the English and Welsh WRAs, the NRA and HMIP and other environmental responsibilities[13]. SEPA takes over the present functions of Scottish WRAs, the RPAs, HMIPI and local authority air pollution control[14].

[13] Environment Act 1995 Sections 2, 5 & 37.
[14] Environment Act 1995 Sections 21, 24 and 25.

3.18 Section 57 of the Act also amends the provisions of EPA90 for the remediation of contaminated land. The amended provisions do not normally apply to landfills where a licence is still in force[15], but can apply to a completed landfill.

National health and safety legislation

Health and Safety at Work etc. Act 1974

3.19 The primary legislation for health and safety is the Health and Safety at Work etc. Act 1974. The most relevant secondary legislation is

- the Control of Substances Hazardous to Health Regulations 1994
- the Construction (Design and Management) Regulations 1994.

The ways in which these Regulations affect and influence the work of designers, operators and contractors are dealt with later in this Paper[16].

National policy guidance

Planning Policy Guidance Notes

3.20 The Government's Planning Policy Guidance notes give guidance on policy issues that affect the planning control of developments in England or England and Wales.

- PPG 23 discusses sources of confusion in the apparent overlap between development control under planning law, and development control resulting from pollution control laws. It is particularly relevant to waste treatment and disposal sites.

In Scotland National Planning Policy Guidelines have the same function. A consultation draft for waste disposal has been issued.

Mineral Planning Guidance Notes

3.21 The Government's Mineral Planning Guidance notes[17] offer guidance on

- planning control of mineral workings
- planning policy for mineral workings including mineral workings subsequently landfilled.

- MPG7 is specifically concerned with the reclamation of mineral sites; other MPGs give guidance related to particular mineral sectors.

In Scotland the equivalents are the National Planning Policy Guidance (NPPG) series.

[15] Section 78 of EPA90 amended by Section 57 of Environment Act 1995.
[16] See Appendix F and WMP 26B for more information about health and safety matters directly relevant to engineering design and operation.
[17] See Appendix C for full list of MPGs and PPGs.

Waste Management Papers

3.22 The DOE's waste management papers provide guidance to the waste management industry on good practice. Some of these papers provide statutory guidance[18], that is guidance which waste regulatory bodies and LPAs must take into account. The papers include others in the WMP 26 series (see Chapter 1), WMP 4 and 4A Licensing of Waste Management Facilities and WMP 27 Landfill Gas. The guidance in this paper, 26E, is not statutory.

National Rivers Authority guidance

3.23 The Policy and Practice for the Protection of Groundwater present the NRA's policy framework for protecting groundwater. It contains

- the methodology for the classification of groundwater vulnerability
- definition of source protection zones
- statements on the protection policy in relation to waste disposal on land.

The NRA have also published their *Position Statement on Landfill and the Water Environment.*

3.24 The Groundwater Protection Strategy for Scotland presents the Association of Directors and Rivers Inspectors of Scotland (ADRIS) equivalent framework for Scotland.

Local planning framework

Development plans

3.25 A planning application for a landfill must be determined in accordance with the development plan unless material considerations indicate otherwise[19]. Development plans consist of

- structure plans - strategic policies
- district-wide local plans
- waste local plans and mineral local plans, which may be combined
- unitary development plans (UDPs) Parts I and II, which combine the functions of the above.

Metropolitan authorities in England have to prepare UDPs, as do some other statutory authorities. Where there are two tiers of county and district authorities, the county prepares the structure plan and also waste and mineral local plans.

[18] WMP 4 and 26A provide statutory guidance.

[19] Part II of the Town and Country Planning Act 1990 (as amended). PPG1 General Policy and Principles. NPPG1 The Planning System (in Scotland). PPG12 Development Plans and Regional Planning Guidance.

3.26 The development plan may contain policies relevant to site selection and the choice of after-use. It will also contain information on planning designations (landscape quality, ecology, cultural heritage) that the designer should take into account.

Waste disposal plans

3.27 The waste disposal plan is prepared by the waste regulatory body. It is concerned with the strategic aspects of treating and disposing of waste. The plan includes

- waste arisings within the area of the plan
- waste treatment and disposal methods
- existing and future strategies for waste disposal
- protection of the environment
- use of waste as a resource.

These plans will be superseded by the Waste Strategy for England and Wales to be published by DOE, and a Scottish Waste Strategy to be produced by SEPA.

Role of the LPA and the waste regulatory body in controlling restoration and aftercare

3.28 The applicant should discuss his proposed application with the LPA and waste regulatory body. At these pre-applications meetings the applicant should find out

- what information should support his planning application
- the level of detail required on each particular aspect
- whether an Environmental Statement should accompany the planning application, (if his proposal falls within Schedule 2 of the Environmental Assessment Regulations).

3.29 During the consultation period, before a decision is taken on a planning application, the LPA seeks the views of a number of statutory and non-statutory consultees, principally the Environment Agency and, in Scotland, SEPA. The full list of consultees is given in Table 3.2.

3.30 The applicant may apply to the waste regulatory body for a waste management licence at any time[20]. The waste regulatory body can only grant a waste management licence after planning consent has been given: so it makes sense to run the licence application in parallel with the planning application. The LPA and waste regulatory body liaise to ensure that the conditions they impose are comprehensive, non-contradictory, practical and achievable.

[20] WMP4 for more information on Waste Management Licensing.

3.31 The conditions have tended to vary from one authority to another:

- some authorities base highly detailed conditions on the applicant's proposed working plan

- others prefer to set broad conditions which oblige the applicant to provide detailed information as the operation develops.

Considering the long timescales for landfilling, restoration, aftercare and post closure management, this second approach is preferable as it allows detailed decisions to reflect the situation at the time of implementation.

3.32 Table 3.3 summarises the information that an applicant may need to consider in preparing a planning application and a waste management licence application.

3.33 The Town and Country Planning Act 1990 empowers mineral planning authorities to impose an aftercare condition for up to 5 years for all permissions which are also subject to restoration conditions: that is, replacement of topsoil, subsoil and soil-making materials. This power was extended to landfill decisions by the Planning and Compensation Act 1991. The planning authority must consult

- MAFF (England) and WOAD (Wales), on agricultural aftercare conditions

- Forestry Authority on woodland aftercare conditions.

3.34 The planning authority may also use a section 106 agreement (in Scotland, section 50 agreement) to control the aftercare of the site beyond the 5 year period and ensure suitable provision for financing: see Chapter 2. This type of long term aftercare is sometimes covered instead by management plans submitted with planning applications, but the Section 106 agreement is more widespread.

3.35 Once the operation is under way, the operations on site will be controlled by either the planning conditions or the waste management licence conditions. Principal control will be as follows:

- site preparation and development - most of these operations are likely to be controlled by planning conditions, but pollution control systems, lining and leachate systems will be subject to waste management licence conditions.

- Landfilling - mainly subject to waste management licence conditions, but planning conditions will relate to protection of local amenity: such as operating hours and landscape screening.

- Installation of pollution control systems - mainly subject to waste management licence conditions.

- Restoration and aftercare - mainly subject to planning conditions but taking due account of licence requirements.

- Post-closure management - controlled by waste management licence conditions.

The LPA and waste regulatory body should consider whether to co-ordinate the monitoring of planning and waste management licence compliance throughout the life of the site.

3.36 Once the WRA is satisfied that the waste is not likely to pollute or cause harm to the environment for that site it may issue a certificate of completion[21]. Under Section 43 of EPA 90 it is possible for applicants to appeal against a refusal to issue a certificate of completion.

[21] EPA 90 Sections 39 (5), (6) and (9).

Table 3.1 Main legislation and guidance relating to landfill restoration and aftercare (England, Wales and Scotland)

Planning	
Acts and Regulations Town and Country Planning Act 1990. Town and Country Planning (Scotland) Act 1972. Planning and Compensation Act 1991. Town and Country Planning General Development Order 1988 (plus amendments 1995). Town and Country Planning General Development Procedure (Scotland) Order 1992. Town and Country Planning General Permitted Development (Scotland) Order 1992 (as amended). Town and Country Planning (Assessment of Environmental Effects) Regulations 1988. The Environmental Assessment (Scotland) Regulations 1988 (as amended).	*Guidance* DoE Circular 15/88 SDD Circular 13/88 Environmental Assessment 1988 PPG 23 Planning and Pollution Control 1994/NPPG Land for Waste Disposal (Draft 1994) MPG7 The Reclamation of Mineral Workings
Pollution control, water quality and waste management licensing	
Acts and Regulations Environment Act 1995. Environmental Protection Act 1990. Controlled Waste Regulations 1992. Environmental Protection (Duty of Care) Regulations 1991. Waste Management Licensing Regulations 1994. Waste Management Licensing (Amendment) Regulations 1995. Control of Pollution (Amendment) Act 1989.	*Guidance* WMP4 *Licensing of Waste Management Facilities.* WMP27 *Landfill Gas.* WMP26A *Landfill Completion.* WMP26B *Landfill Design, Construction and Operational Practice.* WMP26D *Landfill Monitoring* (in preparation 1996). WMP26F *Landfill Co-disposal* (in preparation 1996). DoE Circular 11/94 Scottish Office Circular 10/94, Welsh Office Circular 26/94: EPA 1990 Part 2 Waste Management Licensing. NRA *Policy and Practice for the Protection of Groundwater 1992.* *Groundwater Protection Strategy for Scotland* (in press 1995).
Health and Safety	
Acts and Regulations Health and Safety at Work etc. Act 1974. Management of Health and Safety at Work Regulations 1992. Control of Substances Hazardous to Health Regulations 1994. The Construction (Design and Management) Regulations 1994.	*Guidance* *HSE COSHH Assessments: A step by step guide to assessment and the skills needed for it.* 1988.

Table 3.2 Statutory and non statutory consultees

Consultee	Subject	Statutory/Non statutory
Health and Safety Executive.	Safety of operations.	Statutory consultee on all planning and licence applications.
Ministry of Agriculture Fisheries and Food (MAFF). Welsh Office Agriculture Division (WOAD).	Agricultural land quality. Farm structure.	Statutorily consulted on applications that might lead to loss of significant areas of high quality land.
Scottish Office Agriculture. Environment and Fisheries (SOAEFD).	Aftercare conditions.	Statutorily consulted on the agricultural aftercare and their imposition. Non-statutory advice on aftercare issues to planning authorities.
	Environmentally sensitive areas.	Non-statutory consultations on matters involving soils and agricultural restoration.
English Nature. Countryside Council for Wales. Scottish Natural Heritage.	Site of Special Scientific Interest (SSSI). National Nature Reserve (NNR).	Statutory consultee on applications affecting these designations.
	Local nature reserve (LNR). Nature conservation.	Non-statutory consultee on local matters and proposals for restoration involving nature conservation
Forestry Commission.	Woodland.	Statutory consultee on aftercare conditions relating to woodland. Non-statutory advice on restoration proposals including woodland
English Heritage. Welsh Historic Monuments. Historic Scotland.	Scheduled monuments. Listed buildings.	Statutory consultation on proposals affecting these designations.
	Archaeological sites.	Non-statutory consultation on other areas of archaeological interest.
Environment Agency SEPA (in Scotland).	Protection of water resources.	Statutory consultee on all planning and licence applications
		Statutory consultees on all aspects of planning application.

Table 3.2 (contd) Statutory and non statutory consultees

Consultee	Subject	Statutory/Non Statutory
Local authority consultees Where planning and licence application are submitted, a number of different departments of the authority may be approached for consultation on the following aspects, depending on the individual nature of each application.		
Local Authority - Highways Department.	Traffic.	
Local Authority Environmental Health Department.	Hazardous materials Nuisance (noise, odour, smoke,fumes).	
Planning/Nature Conservation Department.	Nature conservation Tree preservation orders.	
Footpaths officer.	Public rights of way.	
Planning/Landscape Department.	Local landscape designations	
County archaeologist.	Sites of archaeological importance and requirements for non-invasive and invasive field investigations.	
Ramblers Association.	Public rights of way.	Non-statutory.
Local wildlife trust.	Areas of local nature conservation interest.	Non-statutory.
Local amenity groups, Parish Council.	Local amenities.	Non-statutory.

Table 3.3 Information which may accompany the planning application (PA) and waste management licence application (WMLA)

Subject	PA	WMLA (if applicable)
1 Site location plan.	To locate the site on an Ordnance Survey plan and give an OS map reference.	As for PA.
2 Application area.	Extent of planning application.	Extent of area where site licence is being sought. Area and depth of filling, nature of fill materials within each area.
3 Site survey plan.	Existing ground levels prior to filling.	As for PA.
4 Existing ground conditions.	The extent and nature of any unstable ground (e.g. old mine workings, location of adits and shafts, naturally unstable slopes). Provisions to prevent settlement or slippage.	As for PA.
5 Existing land uses.	Land use, including trees, hedges etc.	As for PA.
6 Geology.	Details of the geology of the site, volumes of overburden, soils, other restoration materials.	As for PA. Materials to be used for capping. Give details of geology surrounding the site and within the catchment, including the details of any mineral deposits beneath or adjacent to it.
7 Hydrology and Hydrogeology.	As for WMLA.	Information on a) groundwater, b) surface watercourses on or adjacent to the site and c) agricultural drainage systems, which might be affected by the proposals, both on the site and within the catchment. Effects of new landform on hydrology. Measures to i) prevent pollution of nearby watercourses and groundwater, and ii) to control water on or around the site: in either case these may include pumping, sealing, diversion of watercourses, new drainage outfalls.

Subject	PA	WMLA (if applicable)
8 Soils.	Soil resources for restoration. Include a plan showing the different soil types to be stripped and handled separately. If soils are to be imported state quantity needed. Proposed topsoil and subsoil depths.	Background information.
9 Agricultural land quality, agricultural land classification (ALC), England and Wales. Land capability for agriculture (LCA) in Scotland.	Present a formal description of the ALC grades or LCA classes on site, including other physical characteristics such as slopes and landform. Ideally agree with MAFF or SOAEFD before formal submission of the application.	A useful reference for WRA and engineers, so that they know of where high quality and poorer quality land exists: this knowledge may influence how and when their operations are carried out.
10 Landscape features.	Landscape character assessment and a visual intrusion assessment.	Background information.
11 Cultural heritage.	Presentation of non invasive and invasive fieldwork to identify resources.	Background information.
12 Ecology or wildlife resources.	Presentation of habitat survey and any protected species information; the impact of the proposal on wildlife.	Background information.
13 Landfill with controlled waste.	As for WMLA.	Proposed types, quantities and sources of wastes; areas and depths of filling.
14 Method of working.	Include information on the location and dimensions of storage areas for topsoil, subsoil, overburden, material for containment (if applicable) and the volumes of each storage heap. Outline who will be responsible for site development, operations, environmental protection and operation.	How the restoration is to be filled, and integrated with this. Details should also be given on the method of filling (e.g. cell or area method), with specifications to be used.
15 Proposed method of soil handling and restoration.	How soils are to be transported to and from storage areas. Procedures and equipment to be used for soil handling.	

Subject	PA	WMLA (if applicable)
16 Measures proposed to line and cap landfill sites.	Outline of system(s) and materials to be used.	As for PA, only in more detail. See guidance in Waste Management Paper 26B.
17 Landfill gas systems for control and utilisation.	As for WMLA.	Detailed description of design,location and lay-out of gas control system, including gas compound. Programme for installation. Measures to reduce impact on after-use. Post-closure management of system. Migration monitoring arrangements, and measures to protect adjacent properties.
18 Leachate systems.	As for WMLA.	Description and location of leachate extraction, treatment and monitoring systems. Leachate disposal arrangements. Measures to protect adjacent properties.
19 Anticipated final.	Proposed landform (contoured landform plans and sections); volumes of material required to do this (either on site or to be imported). Angle of slopes; anticipated amount of settlement. Position of surface water courses and outfalls. Check the stability of soils on slopes proposed.	As for PA, only in more detail.
20 Final restored land use.	Description of the intended afteruse(s)	As for PA - identify how the end use will be integrated with the. operations to monitor leachates. and LFG.
21 Aftercare.	General strategy for the aftercare period and specification for initial period. Set out how any post closure landfill controls are to be integrated with the aftercare programme (e.g. damage caused to soils by gas system maintenance).	As for PA.
22 Monitoring of settlement.	As for WMLA.	How frequently will surveys be carried out to monitor settlement; outline remedial measures if these are needed.

Subject	PA	WMLA (if applicable)
23 Monitoring of gas and leachates and associated works in post closure period.		Outline the methods to be used to monitor landfill gas and leachates. If gas is to be extracted for commercial purposes, provide plans and description of works required within time scale. How disturbance to recently reclaimed areas will be minimised.
24 Beyond the aftercare period.	How is the site to be managed beyond the five year aftercare period and how will this be controlled?	Provisions to monitor the landfill gas and leachates. How these operations will be integrated with the after-use.

Chapter 4

Choice of after-use

Introduction

4.1 This chapter discusses

- the range of options for the after-use of a landfill site
- the opportunities and constraints that need to be considered before the after-use is selected.

4.2 Selecting the after-use is a consultative process. The initial choice may be based on the development plan land use policies or the landowner's requirements. The final choice depends on the results of the assessment work described in Chapter 5.

4.3 The guidance offered in this paper about suitable after-uses relates only to post-closure landfill sites. Advice on contaminated land generally is covered in separate statutory guidance.

Range of options

4.4 The range of after-use options includes

- agriculture
- woodland
- amenity/nature conservation
- hard end uses.

On many sites a combination of different after-uses often results in a more attractive and useful final result.

Opportunities and constraints to selection of options

4.5 After-use decisions on new sites (and on old sites with no agreed after-use) involve

- initial consultation with the LPA in the context of the development plan
- consideration of the site specific factors listed in 4.8.

This will be assisted by the results of site assessment work.

4.6 The after-use decisions will also be influenced by

- scheme economics
- the types of waste the operator intends to accept.

4.7 The LPA may need to review with the operator the proposed after-use for an old permission if it is no longer appropriate in the light of

- changed priorities for land use in the area
- the inherent potential or constraints of the site (in terms of such things as final contours and available soil).

4.8 Paragraphs 4.9 to 4.23 discuss five kinds of constraint on after-use. They are

1. the requirements of the local planning authority, the landowner and others with a statutory or landed interest.
2. The character of the area surrounding the site.
3. The individual characteristics of the site.
4. The long term management of the site.
5. The scheme's economics - void space, future income following completion of landfilling.

1 Requirements of those with an interest

Planning authority

4.9 The development plan policies can affect the choice of after-use[22]: see Chapter 3. Policies that affect after-use include

- the development of nature conservation areas
- the promotion of recreational or open space uses
- the development of woodland.

In addition, the local planning authority may use the pre-application discussions (see Chapter 3) to give advice about

- emerging policies and land use strategies
- its preference for a given after-use on an individual site.

Landowner

4.10 The landowner may be in a position to impose a specific after-use.

[22] See also PPG and MPG guidance

2 Character of surrounding area

4.11 The chosen after-use should enable the site to be integrated into the surrounding area.

- This will particularly apply to an agricultural after-use, whose type will, to some extent, depend on the farming regimes in the surrounding area.

4.12 When the after-use option is being selected, the designer must consider whether a proposed after-use would suit the locality. For example

- an ecologically sensitive restoration might not survive in an urban area (where it could not be easily protected)
- a Country Park might go unused if it had poor access.

3 Site characteristics

Soil

4.13 The site characteristics, and in particular the availability of soils for restoration, are critical in the choice of an after-use. On a greenfield site the choice of after-use depends on

- the existing soil type
- soil profile conditions.

The site's restoration specification is designed to reinstate a soil profile equivalent to the greenfield soil profile. Additional materials for environmental protection are supplied from overburden or soil-making materials. Subject to other constraints, these arrangements should permit the same potential for after-use after landfilling as the site initially possessed.

4.14 Difficulties in landfill restoration have often been due to

- the lack of suitable restoration materials
- the loss of these materials,

leading to unsuccessful attempts to comply with planning conditions. A site that was previously derelict may have no suitable soils. Importing soils may cause severe disturbance to local residents.

4.15 If the site has little or no topsoil the designer should consider woodland, amenity or wildlife after-uses that do not need topsoil. These after-uses may also be successful if non-soil or soil-making materials exist on site, which can be added to, or replace subsoil.

Type of waste

4.16 The type of waste which the site is to accept will also influence the choice of after-use.

- A site that is to take largely inert wastes is capable of a wide range of after-uses, including hard development.
- A site that is to accept biodegradable wastes, especially a deep site, will probably not be suitable for a hard end use (unless the operator undertakes costly protective and construction measures). It should be considered for soft end uses such as agriculture, amenity and woodland instead.

Size, location and access

4.17 Size, location and access will also influence the choice of after-use.

- ► A small site is unlikely to be attractive for an agricultural after-use unless it can be combined with an adjacent holding.
- ► A site in an urban location will be more suitable for amenity or redevelopment than for agriculture.

4 Long term management

4.18 The long term management of the site is an important consideration in choosing the intended after-use. Historically, most sites have been restored to agriculture and the long term management has usually passed to the farmer. However, farmers in some areas are reluctant to take back restored landfilled sites. When the operator is reviewing the after-use options he must take account of whether, and how, each after-use can be maintained.

4.19 In considering the options the operator should evaluate each option against the following three criteria for long term management.

- Can the operator invest a person or organisation with specific responsibility for aftercare and long term management?
- Can the operator identify and secure financial resources to manage the land for the after-use during the aftercare period and beyond?
- How, in practice, will the operator establish and maintain the chosen after-use?

4.20 The initial choice of after-use may be amended following evaluation of all site-specific characteristics. Land use requirements change with time and the choice of after-use, and the landfill design, should not limit the future potential of the land.

5 Scheme economics

4.21 Scheme economics are dependent upon

- costs of land, site development and environmental protection
- income from incoming waste and gas utilisation
- costs of restoration and aftercare
- income from the after-use.

4.22 After-use income will come from the sale of agricultural crops and commercial woodland products, and rents from grazing land and some recreational pursuits.

4.23 The operator should consider the costs of restoration and aftercare against the income that can be expected from the after-use. Thus, if there is no topsoil on site

- costs of agricultural restoration may exceed the likely income, especially where there is little demand for agricultural land
- restoration to amenity woodland or nature conservation, whilst generating little or no income, will not cost as much as agricultural restoration.

Considerations for specific after-uses

4.24 The rest of this chapter examines four categories of after-use

- agriculture: paragraphs 4.25 to 4.38
- tree and shrub planting: paragraphs 4.39 to 4.42
- amenity and nature conservation: paragraphs 4.43 to 4.48
- hard end uses: paragraphs 4.49 to 4.50.

Agriculture

4.25 The commonest after-use for landfilled sites has been agriculture, usually pasture. This was due to

- the importance attached to agricultural production
- concern that other after-uses might affect the safety of landfill operation: for example WMP26 (1986) discouraged operators from planting trees on capped landfills; this advice is being reviewed, see paragraphs 2.39 to 2.46 above.

4.26 Agricultural aftercare on landfill sites must now conform to the more exacting standards for mineral extraction sites: see Chapter 3[23]. Hence the agricultural after-use specified in some older planning permissions is now considered inappropriate or impractical. Operators and planners should work together to amend or change the after-use in these permissions.

[23] Planning and Compensation Act: restoration and aftercare controls.

4.27 Reasons **for** agricultural restoration include

- preserving high quality land
- landowner requirements
- agriculture is a widely acceptable after-use
- farmland is easily managed and may generate income.

4.28 Current Government policy[24] is to safeguard high quality agricultural land[25]. If the operator proposes to use large areas of land of this quality for landfill, he must usually satisfy the planners and the agriculture authority that

- the land will be restored to an equivalent quality
- its potential for cropping will not be diminished by gas and leachate control systems.

Restoration to green after-uses, other than agriculture, may sometimes be permitted on 'best and most versatile' land, but restoration and after-use must safeguard the long term potential of the land.

4.29 A very common reason for restoration to agriculture is simply that the landowner demands it. Some farmers are seeking additional income by having a landfill operation on their farm, but they will almost invariably expect to have farmland back in due course.

4.30 Few people object to agricultural land in rural areas. The general acceptability of agriculture is a powerful argument in favour of agricultural restoration.

4.31 The income from grazing or cropping may wholly or partly offset the cost of aftercare: it may meet the cost of establishing the initial grass cover as well as subsequent maintenance costs. Arable restoration is technically more demanding and may be less profitable; without some form of risk-sharing arrangement the landfill operator might have to accept that arable will be a loss-making after-use.

4.32 Reasons **against** agricultural restoration include

- the current limited demand for restored agricultural land in some areas
- costs of restoration
- lack of soils
- location and access problems
- the impact of leachate and gas control installations.

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[24] PPG7 The Countryside and the Rural Economy.
[25] ALC Grades 1, 2 and 3a 'best and most versatile' in England and Wales; LCA Classes 1, 2 and 3.1 'prime land' in Scotland.

4.33 The designer and operator should evaluate proposals for agricultural restoration in the light of the current demand for restored agricultural land. They should also apply farming criteria: access for machinery, size of fields and local farming practice, in addition to economics.

4.34 The costs of restoring land to a standard suitable for agriculture, especially arable, are likely to be higher than for other after-uses. Even if the land is to be used for grazing, restoration still includes the cost of secure fencing and water supplies.

4.35 Agricultural restoration over landfill is feasible where there is adequate soil on site. Sites restored with imported or substitute soil will only be suitable for pasture.

4.36 Many landfill sites are on the edge of cities, where damage to fences, disturbance to stock and unauthorised access cause problems. Conversely an isolated location and difficult access for farm machinery also make some landfills an unattractive proposition for agricultural after-use.

4.37 Arable farming is more efficiently carried out in open fields with no obstructions. A restored landfill site encumbered with gas and leachate control systems will have considerable practical problems: see Chapters 6 and 9.

4.38 Decisions must be site-specific, but for some sites a non agricultural after-use, such as woodland, amenity, nature conservation or hard end use, will be a better choice. These are now considered.

Tree and shrub planting

4.39 Tree and shrub planting is a necessary or beneficial part of restoration on most sites. It may include hedgerows, copses, shelterbelts, amenity and commercial woodland. Tree planting is commonly combined with other after-uses to give a more natural and attractive restored landscape: see Chapter 10.

4.40 When considering the extent of tree planting, the designer must take account of the following:

- the character of the surrounding landscape and whether tree planting is appropriate in landscape terms.
- The type of fill and the age of the site - to assess
    - whether a landfill gas control system will be needed
    - the potential conflicts between aftercare and gas control: see Chapter 2.
- The site's location, climate and exposure to wind - particularly if the purpose of the woodland is commercial cropping.

4.41 Where woodland is the proposed after-use, the **aim** of the woodland must also be considered:

- woodland managed for commercial production (timber, coppice products, or energy) must meet commercial standards of size, access and gradients

- amenity or wildlife woodland is less demanding.

4.42 If the operator has a commercial woodland after-use in mind, he should consult the Forestry Authority. If an amenity woodland is proposed, the operator should consult both the Forestry Authority and the local authority nature conservation department.

Amenity and nature conservation

4.43 When considering amenity or nature conservation as an after-use, the operator should consult the local plan. The strategy for the provision of open space for amenity will be contained in the UDP, structure plan or district local plan. Most authorities will have target requirements for open space, including amenity grassland, sports pitches and children's play areas.

4.44 Nature conservation will often be a suitable after-use in both the country and town. It may attract significant support and interest from the public who will be inclined to see it as beneficial, particularly if the site is closed, neglected and seen as a source of nuisance.

4.45 Many local authorities have published nature conservation strategies (also called ecology plans, green strategies, green plans etc.). Many such plans identify *green corridors* or *wildlife corridors* connecting areas of wildlife value. Other authorities designate areas of wildlife (or heritage) value where the conservation of the existing wildlife is considered a high priority. These nature conservation initiatives are usually supported by environmental policies in the UDP or district plan.

- The operator should consult these documents when making decisions about after-use.

4.46 Long term financial provision must be considered at the planning stage. Local authorities may undertake the management of amenity or nature conservation sites, but usually require financial support from the operator. The cost of management for amenity woodland, amenity grassland and nature conservation is significantly less than for agriculture, but the potential for income is also much less.

4.47 When considering an amenity or nature conservation after-use the designer must take account of

- the local community needs and aspirations: they may influence the choice of after-use and its design.

- The surroundings of the site: some after-uses will be more appropriate than others.

- The type of fill and the age of the site: the designer must consider whether the after-use will conflict with the efficiency and safety of the environmental protection systems.

- The available soil types: they will influence the choice of vegetation.

- Existing wildlife interest on or near the site.

4.48 Restoration to amenity and nature conservation uses is discussed in detail in Chapter 11.

Hard end uses

4.49 When considering a hard end use, the operator must take account of

- the location: a hard end use may be more in keeping in a built up area particularly if a soft end use would involve importing subsoil and topsoil.

- Economics: development may be more profitable than a soft end use, particularly if the area is short of development land, or the site is in an advantageous position.

- The type of waste and the age of the site: a landfill site which has taken, or is intended to accept, biodegradable waste will pose severe problems resulting from

    - ► unstable and contaminated ground

    - ► landfill gas generation.

The cost and technical difficulties of solving these problems may render uncertain, if not wholly destroy, the benefits of development: see Chapter 12.

4.50 There will be greater opportunities for hard end uses on sites which have taken only inert wastes, and on sites where biodegradation has ceased.

4.51 Hard end uses are considered further in Chapter 12.

Chapter 5

Site assessments

Introduction

5.1 The operator should investigate the characteristics of the site before he undertakes detailed landfill and restoration design. This chapter covers the assessments necessary for this process.

5.2 Certain developments require Environmental Assessment[26], and in these cases the developer must supply information on specific subjects: these are listed in paragraph 5.10. This information will be presented in an Environmental Statement. It will

- identify problems which must be taken into account during the design
- highlight positive features that will be incorporated into the proposal to mitigate potential adverse effects
- summarise the environmental effects of the proposal.

The assessment process will also assist the designer where an Environmental Statement is not legally required.

5.3 The developer must also carry out site investigations to assist in the development and operational design of the site[27].

5.4 This chapter outlines the various assessments which may be necessary in the detailed restoration and aftercare design.

- It is strongly recommended that the site investigation requirements for engineering, monitoring and restoration and aftercare are assessed together to eliminate wasted effort and repeated surveys.

5.5 The need for assessments and their level of detail will depend on

- the type of site being considered
- the requirements of the LPA and waste regulatory body concerned.

The assessments should be planned (scoped) to concentrate effort and resources onto the important aspects.

5.6 This chapter describes the full scope of assessments that may be required for new sites. The scope of assessments for closed or existing sites would generally be more limited and site specific. The techniques of assessment would be the same in either case.

[26] The Town and Country Planning (Assessment of Environmental Effects) Regulations 1988, and Environmental Assessment: A Guide to the Procedures. DOE/Welsh Office.
[27] See WMP26B, Chapter 5.

Site assessments

5.7 There are two stages in carrying out site assessments

- Stage 1 - desk top study
- Stage 2 - detailed assessments.

Stage 1 - Desk top studies

5.8 The desk top studies will provide background to the more detailed on-site assessments. They will

- indicate the scope of further detailed assessments
- highlight immediate environmental concerns or limitations to the site
- obviate (in some circumstances) more detailed investigations.

5.9 Table 5.1 gives the sources of information for desk top studies, and the information they provide.

Table 5.1 Information available from desk top studies

Study	Source	Information
Geology, hydrology and hydrogeology.	British Geological Survey 1:50,000. Ordnance Survey plans. NRA Groundwater Quality Plans.	Identify catchment and surface drainage. characteristics, geological information. Provide flow figures and rainfall types within catchment; aquifer status.
Soil resources.	British Geological Survey 1:50,000. Soil Survey & Land Resource Centre (SSLRC) maps and accompanying bulletins	 Possible nature and depth of restoration material.
Agricultural land quality.	British Geological Survey 1:50,000. Ordnance Survey plans. MAFF/WOAD agricultural land classification maps and reports. SSLRC - LANDIS climate database. Structure/local plan.	Nature of soil materials. Identify any topographic limitations. Quality of agricultural land. Climatic information to determine ALC grade. Local agricultural policies.
Landscape features.	Structure/local plan. Local authority. Ordnance Survey plans. Aerial photographs. Definitive footpath maps.	Information provided on national and local landscape designations - AONB, Green Belt, special landscape areas, etc. Tree preservation order designations Topographical detail indicating nearby houses and other buildings that might be affected. Potential loss of public footpaths and bridleways.

Study	Source	Information
Cultural heritage resources.	English Heritage.	Scheduled Monuments.
	County Council Sites and Monuments Records.	Non statutory designations.
	Borough Council.	Listed buildings.
	Local studies library and map search at County records office.	Any relevant historical information.
	Aerial photographs.	Potential areas of interest.
Ecological/ wildlife resources.	Structure/local plan.	National designations and sites of special scientific interest. Local areas of interest
	English Nature.	Statutory designations on and near the site - sites of special scientific interest.
		Areas of special protection for birds.
	RSPB, local conservation groups.	National nature reserves Areas of special protection for birds.
	County wildlife trusts, local wildlife groups.	Any particular local interests in the vicinity.

Stage 2 - Detailed assessments

5.10 The results of the desk top studies will indicate what detailed assessments are necessary. The Assessment of Environmental Effects Regulations specify that the significant effects, direct and indirect, on the environment by the development must be explained by reference to its possible impact on

- human beings
- flora and fauna
- soil
- water, air and climate
- landscape
- material assets
- cultural heritage.

5.11 The following paragraphs describe the surveys and assessments that the operator should undertake to comply with the Regulations, and to assist the detailed design. They are

- geology, hydrogeology and hydrology: paragraphs 5.12 to 5.15
- soil resources: paragraphs 5.16 to 5.21
- agricultural land quality: paragraphs 5.22 to 5.26
- cultural heritage: paragraphs 5.27 to 5.31
- landscape: paragraphs 5.32 to 5.38
- visual impact: paragraphs 5.39 to 5.44
- ecology and wildlife: paragraphs 5.45 to 5.51
- other assessments - local climate, noise, air quality, traffic, local communities: paragraphs 5.52 to 5.53.

Geology, hydrogeology and hydrology

5.12 The desk top study will have identified the underlying geology in terms of

- rock strata and faults
- past and present mining activities
- potential subsidence
- the status of the groundwater (major, minor or non aquifer).

Borehole investigation will be necessary to confirm and sample the underlying rocks, and to provide information on the groundwater.

5.13 The depths and suitability of each stratum beneath the site must be assessed for

- preparing a stable base for the landfill
- use as capping material
- other construction purposes.

5.14 The designer requires this information primarily for landfill construction[28]. It will also be a material consideration for restoration because it affects

- basic landfill design
- excavation of existing materials for screening and restoration
- suitability of underlying material and soils for restoration
- surface water drainage. The location of permanent points for groundwater monitoring should be taken into account in the landfill and restoration design.

[28] See WMP26B, Chapter 5.

5.15 The quality and importance of surface watercourses on and near the site should also be assessed. If surface water will drain off the site into a local stream, the flow rate of both the stream and the discharge should be calculated.

Soil resources

Published data

5.16 The published data will give an indication of

- the types of materials that exist on site
- their potential textural characteristics
- their overall depth.

They may also alert the developer to any difficulties, such as a likely shortfall of suitable restoration materials: see Chapter 8[29].

5.17 However, the published data will not provide sufficient detail to enable the designer to assess the locations and volumes of particular types of soil material from different areas on an individual site. A more detailed soil survey will therefore be necessary in most cases. This information will be required to

- assess volumes of on-site soils
- assess soil types for restoration
- plan the after-use
- plan soil stripping and replacement programme.

The designer should take this information into account in the detailed design of phasing and restoration.

Soil survey techniques

5.18 The soil's physical characteristics are surveyed by sampling with a hand auger at regular intervals across the site: a 100m grid is quite usual. The sample records the soil profile to 1 - 1.2 m depth. It is supplemented by soil pit analysis within identified soil types.

- The requirements of the soil survey should be taken into account during the geological investigation so that soil inspection and sampling can be done when boreholes are drilled and logged[30].

[29] See Appendix A.
[30] See WMP26B for more details on site investigation techniques

5.19 The soil survey should record

- depths of topsoil and subsoil (upper and lower)
- soil texture, and presence or absence of calcium carbonate (calcareous or non calcareous soils)
- total soil depth
- other important limitations including high stone content
- location and extent of different soil types on site.

5.20 A plan and schedule can be produced to show the significant soil variations across the site (see Figure 8.2 and Table 8.2). This should be used to develop the soil stripping and restoration programme.

5.21 Soils information should be read in conjunction with geological survey information, which may highlight materials below the subsoil suitable for use in restoration. The soil survey may also be used to collect soil samples for chemical analysis.

Agricultural land quality

5.22 In England and Wales land is classified into one of five grades (1 - 5) with Grade 3 subdivided into 3a and 3b[31]. Government policy defines Grades 1, 2 and 3a as the "best and most versatile land"[32]. MAFF require a landfill site which takes `best and most versatile' land to be restored to a standard that safeguards its long term agricultural potential: in practice, the same ALC grade.

- The operator must consider whether the site comprises land in this category, and to what extent this will influence the detailed design.

5.23 Land quality in Scotland is assessed according to the Land Classification for Agriculture (LCA) system. It divides land into one of 7 classes of decreasing qualities with three being referred to as `prime' land, (LCA Classes 1, 2 and 3.1). Classes 1 to 4 are suitable for arable cropping, but lower classes are suitable only for improved grassland or rough grazing.

5.24 The published ALC Sheets (1:63,360), and Scottish LCA sheets at 1: 50,000, indicate potential land quality on a site. However, their accuracy is limited by scale. The ALC sheets are also limited because they were issued before the most recent ALC guidelines were published. A site survey will be needed to produce the detailed agricultural land classification.

5.25 The ALC and soil survey are normally carried out at the same time, using the same sampling methodology. A plan of agricultural land quality is then produced: see Figure 5.1. This will relate to the soil map (see Figure 8.1).

[31] MAFF Agricultural Land Classification (ALC) Guidelines 1988.
[32] PPG 7 The Countryside and the Rural Economy.

5.26 The delineation of soil types on soil maps may not correspond with the boundaries of land quality grades. This is because the soil survey studies the soil characteristics, whilst the land quality assessment is much wider and also includes

- soil types
- climate
- gradients
- drainage characteristics
- erosion risk.

Cultural heritage

5.27 The operator must be aware of his obligations for areas of known or suspected archaeological interest[33]. **Before** he submits a planning application, he must find out whether archaeological remains may exist on the proposed site.

5.28 At an early stage the operator should discuss his proposals with the local authority

- to reconcile the needs of archaeology and the development
- to reduce potential conflicts.

As a result of this discussion he may decide to commission his own archaeological survey.

5.29 Archaeological surveys should be undertaken in stages. The level of detail required at each stage depends on the results of the previous work. The operator should liaise closely with the County Archaeologist during the site assessment process, to ensure that

- the requirements of the authority are met
- no unnecessary site work is carried out.

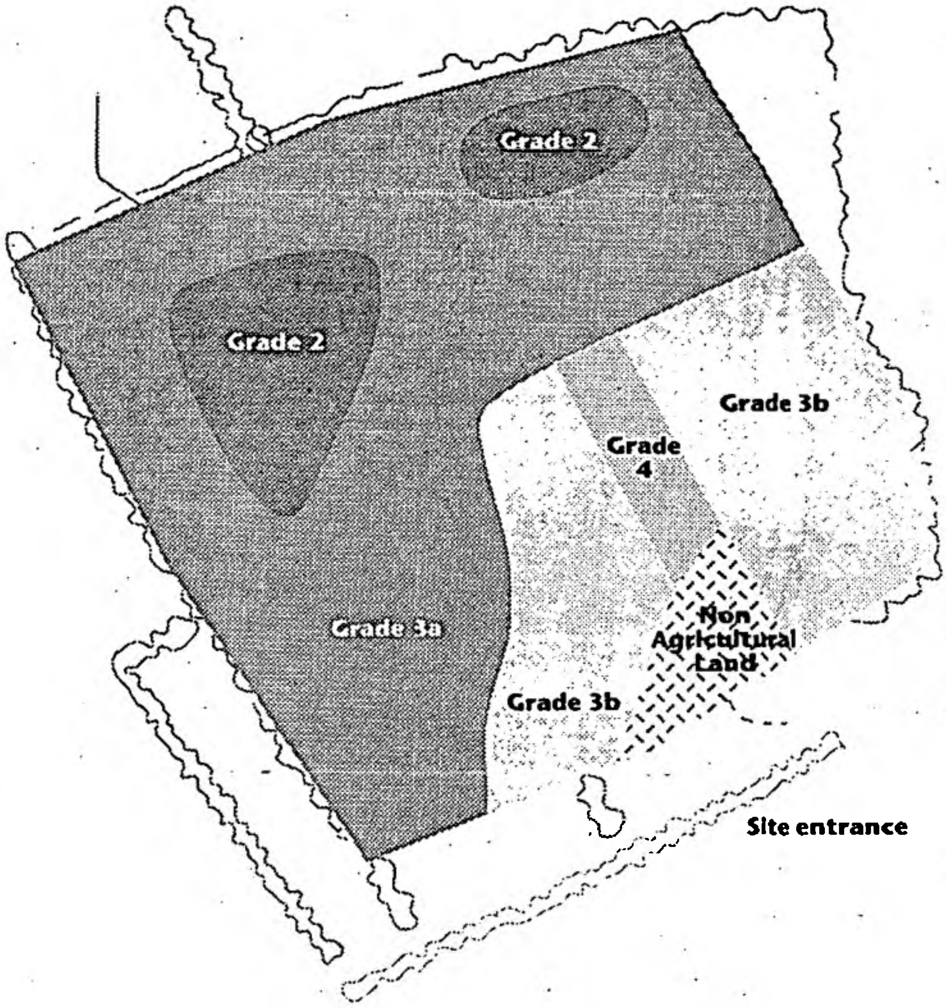
Aerial survey and aerial photography may be very useful in identifying potential areas of interest.

5.30 The stages of an archaeological survey in this context are likely to be

- desk top study - plans, aerial photographs, records etc (see Table 5.1) to locate known areas of archaeological interest
- rapid site walkover - to identify any obvious features not highlighted in the desk top study
- systematic field walking - on a grid basis, usually 10-20m, undertaken when the ground is bare and the soil surface easily visible

[33]PPG 16 Archaeology and Planning.

Figure 5.1 Agricultural land quality plan



- in-depth study of relevant aerial photographs, detailed geophysical surveys (using magnetometry techniques to identify objects below the surface of the ground), trial trenching.

The operator is advised to employ specialist survey firms for detailed archaeological investigations.

5.31 If the area has not been previously studied, a desk top study followed by field walking is likely to be required prior to the planning application to enable the County Archaeologist to decide whether the application is likely to affect areas of archaeological significance.

Landscape

5.32 Landscape assessment of the site itself involves identifying and mapping

- areas of different landscape character
- individual landscape features
- public rights of way.

5.33 Landscape character assessment might include, for example, delineating areas dominated by large agricultural fields and little vegetation, as opposed to an area characterised by small fields with an intricate pattern of hedgerows.

5.34 The assessment of individual on-site features will establish which, if any, of these existing features should be retained and which can be replicated in the landscape and restoration design: see Figure 5.2. For example, a well established hedgerow on the edge of a site may be incorporated into the final design and should be protected during the operational phase of the scheme.

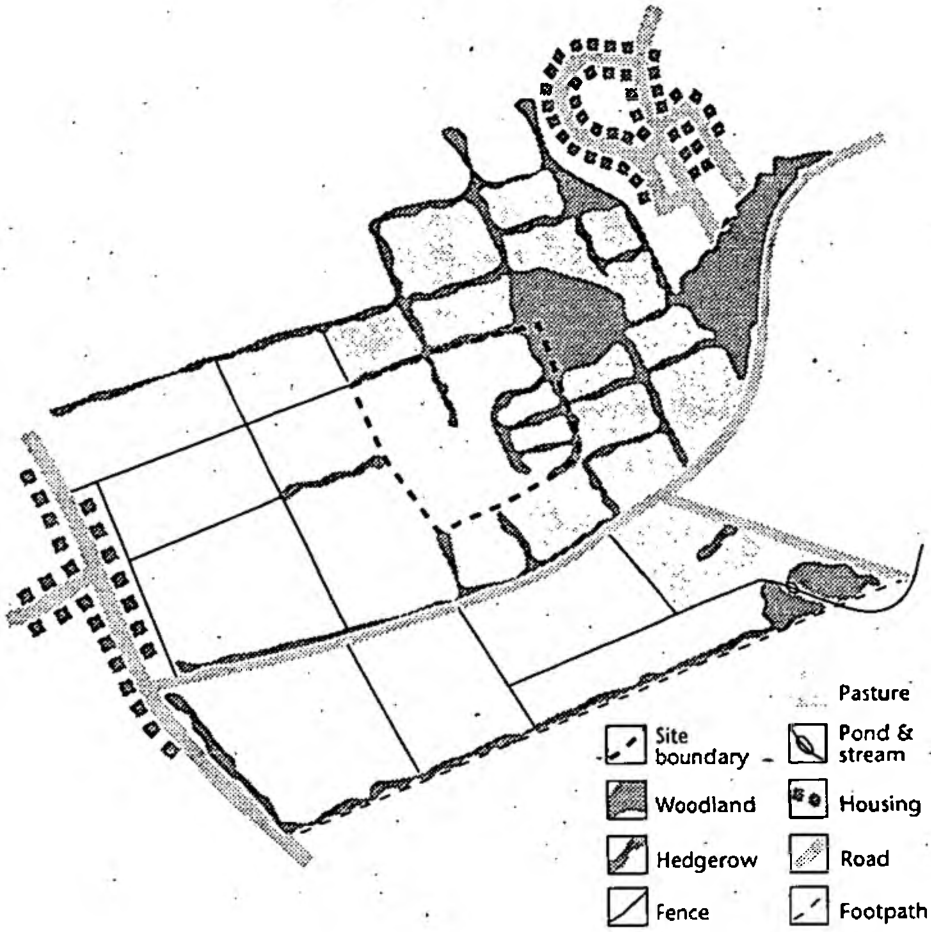
5.35 Other landscape features which might be worthy of protection are

- exposed rock faces and geological features within quarries
- water features such as streams and ponds
- areas of mature woodland.

These features should be shown on drawings of the existing site and restoration proposals and included in the site manual so that this information is available during development and operation.

5.36 If public rights of way will be directly affected by the proposals the applicant should consider applying for a diversion order. This may be either *temporary*, if the path is to be reinstated along its original line during restoration, or *permanent*, if the diverted path is to become the new route. He should start this process as early as possible because it may take many months for the diversion order to be made.

Figure 5.2 Landscape assessment



5.37 The designer must also consider how the site will be integrated into the surrounding area following restoration and aftercare. To do this he must carry out a landscape character assessment of the surrounding area. The methodology suggested by the Countryside Commission for landscape assessment[34] may be adopted if it is appropriate to the site location. The landscape assessment will indicate

- the height and form of the surrounding topography
- the size and shape of fields
- the woodland structure in the general locality
- surrounding land uses in both the rural and urban situation.

5.38 Many areas have characteristic landscape features such as wide hedgerows, hedges raised on banks, stone walls, copses and local steep gradients. These should be noted for use in the landscape design to integrate the site into its surroundings, or to increase the void space without making the landform incongruous.

Visual impact

5.39 The visual impact assessment will determine how many people are likely to be affected visually by the proposal, and will indicate where planting and screening should be included to mitigate any visual intrusion.

5.40 Visual impact may derive from

- visual *intrusion*: where a new feature is introduced into the view
- visual *obstruction*: where a feature obstructs some or all of the existing view.

Both are generally more severe where

- the scheme is raised above existing ground level
- there is vehicle movement
- the colours of the development or activity contrast with the surrounding areas.

A visual impact assessment will be particularly important for landraising schemes, and must demonstrate the visual effect of the elevated landform.

5.41 It will assess the potential views of, and into, the site from

- the surrounding area, in particular from nearby residential areas and other occupied buildings
- public highways, footpaths and bridleways.

[34] Landscape Assessment Guidance. Countryside Commission, CCP 423 1993. Countryside Commission Postal Sales, PO Box 124, Walgrave, Northampton, NN6 9TL.

The assessment normally includes

- study of short views (immediately around the edge of the site)
- study of long views (from more distant locations)
- an assessment of both winter and summer impact.

5.42 The assessment is usually illustrated on a plan (see Figure 5.3) which shows

- the location of key viewpoints
- the degree of visual impact upon occupants or other viewers.

5.43 The designer can illustrate visual effect in more detail with

- cross sections through the final landform from key viewpoints
- computer-generated 3-dimensional representations of the proposed landform which may be superimposed on a photograph of the area
- photographs and photomontages from key viewpoints using helium balloons suspended over the site at the proposed final height.

5.44 The visual impact assessment should be carried out prior to the detailed design stage so that suitable mitigation measures can be included. The initial assessment may need to be reviewed if the proposed contours are adjusted during detailed design. Computer aided design (CAD) software (see Chapter 6) is a useful and efficient means of testing the visual impact of various landforms from key viewpoints; it must not, however, replace the detailed site assessment.

Ecology and wildlife resources

5.45 The ecology survey will investigate and evaluate the wildlife on site and in the surrounding area which may be affected by the scheme.

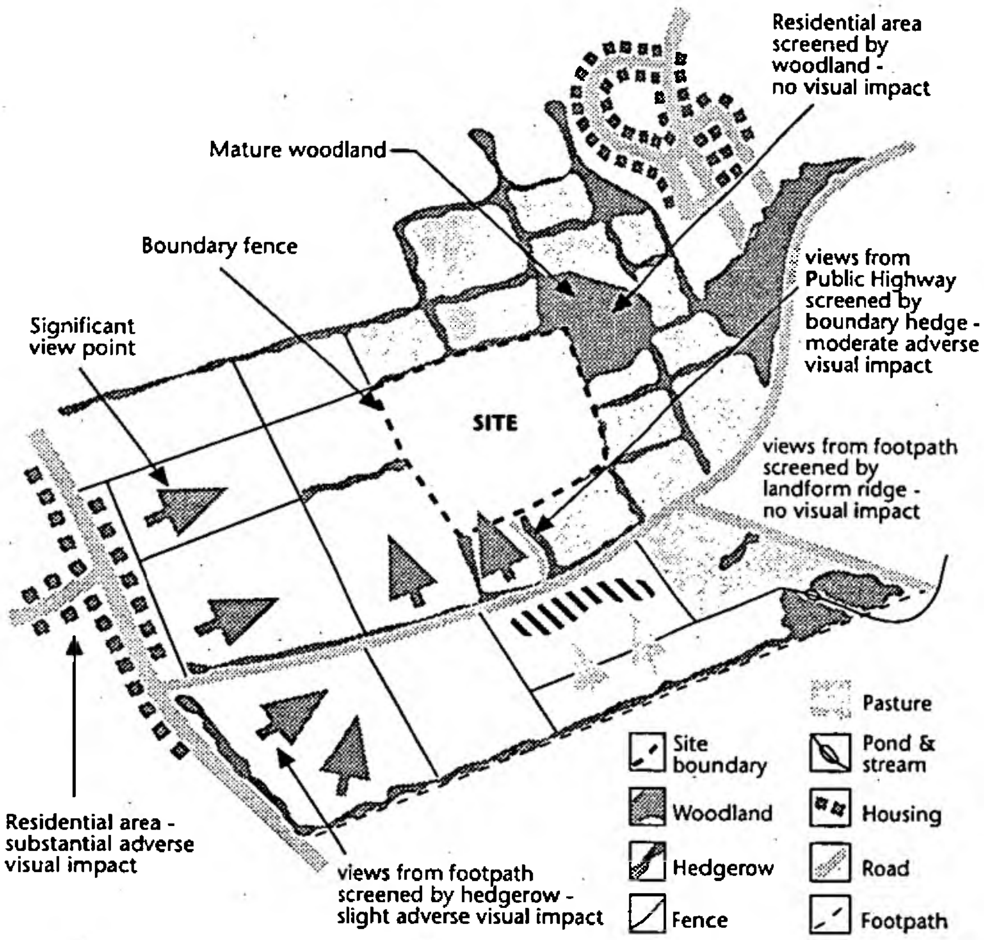
5.46 The desk top study will indicate

- nationally or locally designated sites such as sites of special scientific interest (SSSI), and national or local nature reserves, sites of scientific interest (SSI)
- species, protected under the Wildlife and Countryside Act 1981, which are known to be present in the area.

5.47 Published information can be supplemented by records which are kept by local natural history societies who may be prepared to make their data available. The recorders for these groups are usually volunteers, and may be very sensitive about releasing their information.

5.48 The operator should contact the local wildlife groups, especially if his site may contain ecological interest. If approached at an early stage in the design, and consulted openly about the proposal, these groups may be willing to work with the design team on mitigation and restoration proposals. They may be able to give practical advice on reducing the adverse effects of the scheme on wildlife.

Figure 5.3 Visual impact assessment



5.49 On-site assessment of wildlife habitats is usually conducted in accordance with the Nature Conservancy Council Phase 1 habitat survey methodology[35]. This identifies the vegetation types on the site, and categorises them according to several relevant criteria, including their size, diversity of plant species and rarity. This preliminary survey will indicate the areas of the site where further assessment may be required.

5.50 The importance of the site for birds and animals must not be under-estimated. Even intensively managed arable land may be used by overwintering birds as feeding and roosting areas. Lowland wet, or damp grassland may be important for flocks of migrant waders in the winter, and amphibians (frogs and newts) in the spring. The ecological survey should ideally be conducted during different seasons so as to fully assess the ecology of the site throughout the year.

5.51 The landscape and restoration design should take account of the results of the ecological survey so that

- ecologically interesting areas are protected during the landfilling operations
- important local habitats are re-created during restoration and aftercare.

Other assessments

5.52 Other assessments which may be required under the Assessment of Environmental Effects Regulations are briefly listed here to complete the potential scope of assessments. They include

- *local climate* - rainfall and prevailing wind direction and strength
- *noise* - during construction (short term) and during operation (long term), also traffic noise on approach roads to the site and noise from pollution control equipment such as gas engines, pumps, fans, flare stacks
- *air quality* - dust (both during construction and operation); odours emanating from waste decomposition, leachate, and landfill gas and products of burning or utilising landfill gas
- *traffic* - effect of construction and site traffic on local road network, daily vehicle movements, type of traffic and proportion of heavy goods vehicles, approach roads to site, traffic controls etc.
- *impacts on local communities* - socio-economic impacts.

5.53 Information from these assessments will be used in site design and operational practice and will, in some instances, be relevant to restoration design and strategy.

[35] Handbook for Phase 1 Habitat Survey - A Technique for Environmental Audit. Nature Conservancy Council, 1990.

Chapter 6

Restoration design considerations

Introduction

6.1 This chapter will be of particular relevance to the designer and emphasises the importance of a multi-disciplinary project team in ensuring a holistic approach to landfill design, restoration, aftercare and post-closure management.

6.2 The chapter is not intended to give a prescriptive approach to design, but rather to demonstrate the wide range of design ideas applicable to landfill restoration and aftercare design.

- The designer should use these ideas to balance the requirements of
  - environmental protection during the post closure period
  - restoration and aftercare

  using a risk assessment approach to determine priorities and opportunities.

6.3 The chapter describes

- the project team: paragraphs 6.5 to 6.10
- the design process: paragraphs 6.11 to 6.23
- physical design parameters: paragraphs 6.24 to 6.50
- landscape design considerations: paragraphs 6.51 to 6.74
- landfill phasing design objectives: paragraphs 6.75 to 6.77
- design considerations for engineering systems; ways of integrating capping, landfill gas and leachate systems with restoration: paragraphs 6.78 to 6.114.

6.4 The advice contained in this chapter relates principally to the design of new sites, used to support a planning application. This information is also relevant to the restoration design of closed or existing landfills where the design requires up-dating because of changing local needs or site conditions. Specific design requirements or constraints for closed or existing sites are also identified.

Project team

6.5 The skills needed for the core project team should be

- established at the start of the scheme
- represented (as far as possible within the constraints of staff movements) throughout the life of the site.

6.6 The long time scale of landfill schemes will result in changes to the initial project team. The original project team may not be the same as that responsible for restoration, aftercare and post-closure management.

- The design concepts should be included in the **site manual** which should be used to guide works throughout the continuing life of the site.

6.7 The core project team skills should include

- ► civil engineering
- ► hydrogeology and drainage
- ► operational site management
- ► gas and leachate engineering
- ► landscape design and land reclamation. .

More than one of these skills may be present in an individual project team member. The operator may have these skills in-house or may engage specialist consultants. He may need to employ additional specialist skills, such as an ecologist, if the site demands it.

6.8 The operator must also consider whether the Construction (Design and Management) (CDM) Regulations 1994 apply, in which case a Planning Supervisor (as defined under those Regulations) should be appointed. This could be a suitably qualified member of the project team, given those responsibilities *at the design stage*. The Planning Supervisor will co-ordinate all health and safety issues through design, construction, restoration and aftercare.

6.9 When landfilling has finished the team will become responsible for

- ► restoration and aftercare works
- ► leachate and landfill gas monitoring and control
- ► post-closure management of engineering systems.

6.10 The members of the project team should liaise to produce a design which integrates the engineering systems, landform and after-use to achieve

- ► good standards of design and technical expertise
- ► integration of the technical and aesthetic needs of the site
- ► the most appropriate after-use and restoration design.

The design process

6.11 The basic information needed for design is

- **topographical survey** information as a base for conceptual and subsequent detailed design:
  - this should extend well beyond the site boundaries for landform integration.
  - Aerial survey techniques will reduce access problems.
  - Photographs assist interpretation of survey and map data.
- planning policy or development plan context
- required void space
- access and services information
- physical information such as hydrogeology, geology, soils, landscape and ecology: see Chapter 5.

Computer aided design

6.12 Manual design of the proposed base and restoration contours and manually calculating the effect of design changes on landfill volume are laborious and may be inaccurate. There are several computer aided design (CAD) software packages that

- process survey data
- generate base models
- allow manipulation of proposed contours
- calculate volumes of excavation and fill.

Data from **aerial surveys** may be fed directly into these packages to provide 3-D models of the site and its surroundings, and to map landscape features, archaeology and soils.

- Examples of the more commonly used software products for use on IBM compatible personal computers or work stations are MOSS, AutoCAD and LSS (Land Survey Systems)[36].

6.13 MOSS and LSS are particularly suited to modifying contours and calculating volumes. AutoCAD, which has a range of specially developed third party add-on software packages, may be used for this purpose. It may also be used to prepare detailed contour, construction, phasing and landscape plans, 3-dimensional models from viewpoints around the site and other presentational material, to a high standard.

[36] See Appendix D for more detail on CAD systems.

- AutoCAD packages most useful in digital terrain modelling, civil engineering and landscape work include the American LandCADD, Eagle Point and Softdesk systems, and the British Key systems - Key Civil, Keyscape, KeyDGM and Key Planning.

6.14 Computer design and graphics packages can also be used to

- produce impressions of the landform at different stages throughout the site's life
- illustrate the effectiveness of screening proposals and the advantages of the restoration scheme
- develop photomontages of the site from different viewpoints to show its appearance within the landscape.

6.15 For presentational purposes the designer can improve the appearance of the landscape and restoration design by hand-finishing the computer output.

Conceptual design

6.16 **Conceptual** or **outline design** will produce the basic concept, including

- outline development design
- principles of leachate and gas management
- final contours.

The design team must consider the gas and leachate control systems at the start of the design process.

6.17 The conceptual design should

- be based on a ***risk assessment*** approach, giving due consideration to specific site requirements for pollution control
- be flexible enough to allow modification during detailed design
- take account of the required void space and the types of waste which the site is to accept
- take account of after-use options.
- take into account any features to be protected and retained, such as ecological areas, important landscape features and archaeological remains.

6.18 The extent of the landfill area within the site as a whole will be determined at the conceptual design stage.

Detailed design

6.19 Following agreement of conceptual design proposals, the **main** or ***detailed design*** will commence.

- The first stage in detailed design is detailed site investigation and assessment of environmental issues: see Chapter 5.

The object of detailed design should be to produce integrated proposals for the overall construction, operation and restoration of the site. It will form the basis for the planning application and the working plan for the waste management licence application[37].

6.20 The designer should use a site specific, risk assessment approach during detailed design, rather than standard solutions to problems and constraints, to develop the optimum site design.

6.21 Detailed design will refine the outline design by

- detailing the site liner and pollution control systems[38]
- making any necessary amendments to final contours to ensure landform integration and maintain the required volume
- detailing the phasing of development and restoration, using information on predicted waste input rates
- providing detailed landscape design and restoration proposals.

The designer should integrate the design of pollution control systems and the landscape and restoration design to minimise conflicts during aftercare and post-closure management.

6.22 Detailed design will produce a set of plans, drawings and other material, such as photographs, photomontages and cross sections, suitable to support both the planning application and the waste management licence application.

- They should demonstrate the scheme clearly and comprehensively to planners, regulators, local residents, financiers and others with an interest.

The detailed design would not normally contain construction details which would be drawn up when the necessary permissions have been obtained and tender documents are being prepared. These details may be required by conditions attached to the planning permission.

[37] WMP 26B guidance on design for construction and operation.
[38] For details of leak detection, underdrainage, leachate collection, gas control and cap, see WMP26B, Chapters 6 and 10.

Physical design parameters

6.23 The basic physical parameters which affect restoration and aftercare design of a new site include

- landform design: paragraphs 6.25 to 6.31
- slope gradients: paragraphs 6.32 to 6.41
- hydrogeology: paragraphs 6.42 to 6.44
- hydrology: paragraphs 6.45 and 6.46
- availability of soil: paragraphs 6.47 and 6.48
- interaction with pollution control systems: paragraphs 6.49 and 6.50.

6.24 The designer must integrate these physical parameters with the need for an economic void space and the proposed after-use.

Landform design

6.25 The designer will need to balance the requirement for an economic void space with the potential landscape and visual impacts. Landfill economics are heavily dependent upon the volume of fill which can be achieved and this will influence landform design. The operator may require a minimum void space for economic and strategic reasons. Alternatively he may wish to obtain the maximum void space possible within the site.

6.26 The void space is determined by

- physical constraints, such as the size and shape of a redundant quarry
- the shape of the final landform, defined by the final contours
- the profile of the base of the developed site.

Void space may be increased, particularly in landraising schemes, by excavating the base of the landfill and using the material around the perimeter to screen the operational area. This may be visually more acceptable than raising the height of the finished site or increasing the gradients of side slopes, see Figures 6.1 and 6.2.

- The suitability of this approach will be determined by the local hydrogeology: see paragraphs 6.42 and 6.43.

6.27 The designer must pay great attention to the appearance of the final landform and the proposed after-use of the site. Thus

- in the country the site should blend with the surrounding landscape, with slope gradients which harmonise with local landforms or other features
- in urban areas the landform may not need to conform to the surrounding landform but should enhance the area.

Figure 6.1 Landraising site - increasing void space or reducing visual impact (or both)

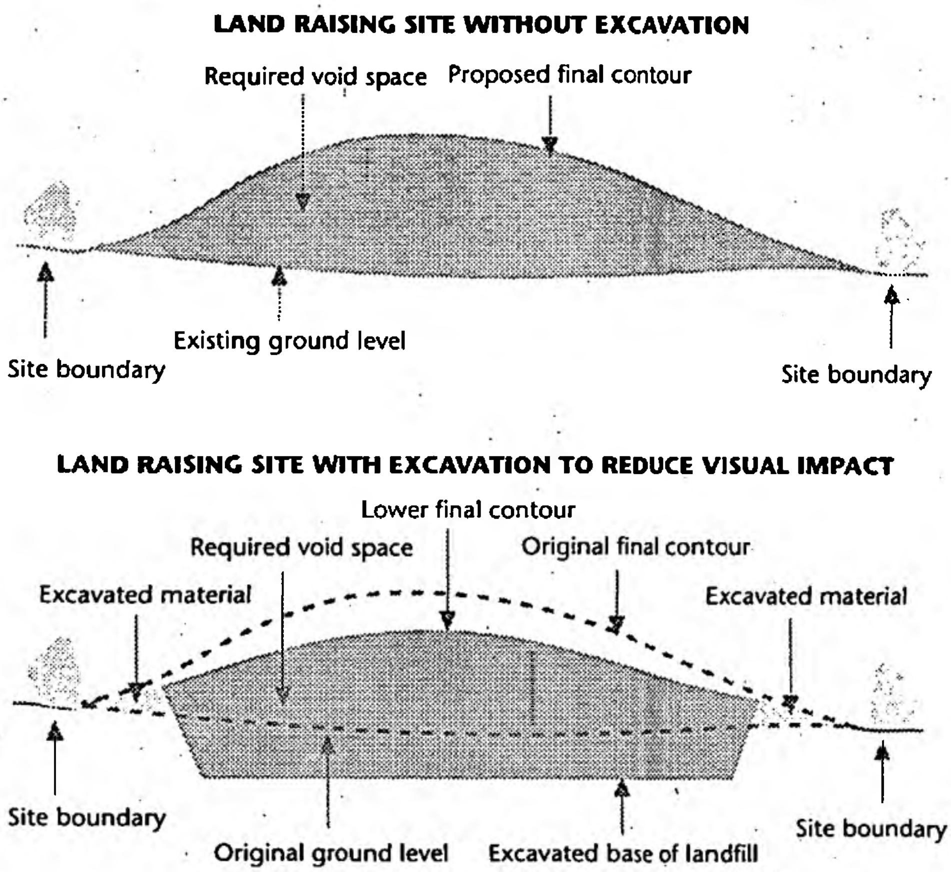
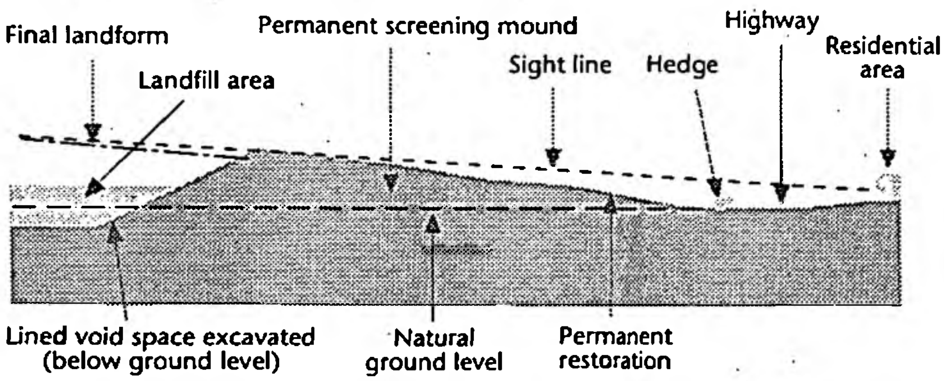


Figure 6.2 Perimeter screening mounds



6.28 The designer should recognise that a site which is to take biodegradable wastes will settle as the waste decomposes. In order to achieve the desired final landform the site must be over-tipped. Surcharge or pre-settlement contours which take account of settlement must be calculated[39].

6.29 If the finished contours on closed sites require amendment, the operator should seek permission from the planning authority to change the landform.

- Proposals to change the landform on existing sites by
  - recontouring the waste
  - importing additional material

should be ***very carefully evaluated*** in terms of environmental effects and benefits.

6.30 The designer should always seek to create an attractive and interesting final landform which reflects natural characteristics. This may be achieved in the following ways

- in a flat landscape, the final landform should be gently domed to promote natural drainage
- the site may be deliberately designed to give visual stimulation in a flat landscape, with careful consideration of the height and scale of the new landform
- in undulating or hilly landscape, steeper slopes can be formed which will look natural
- slope gradients should be varied
- the new landform may have more than one summit for a more natural appearance.

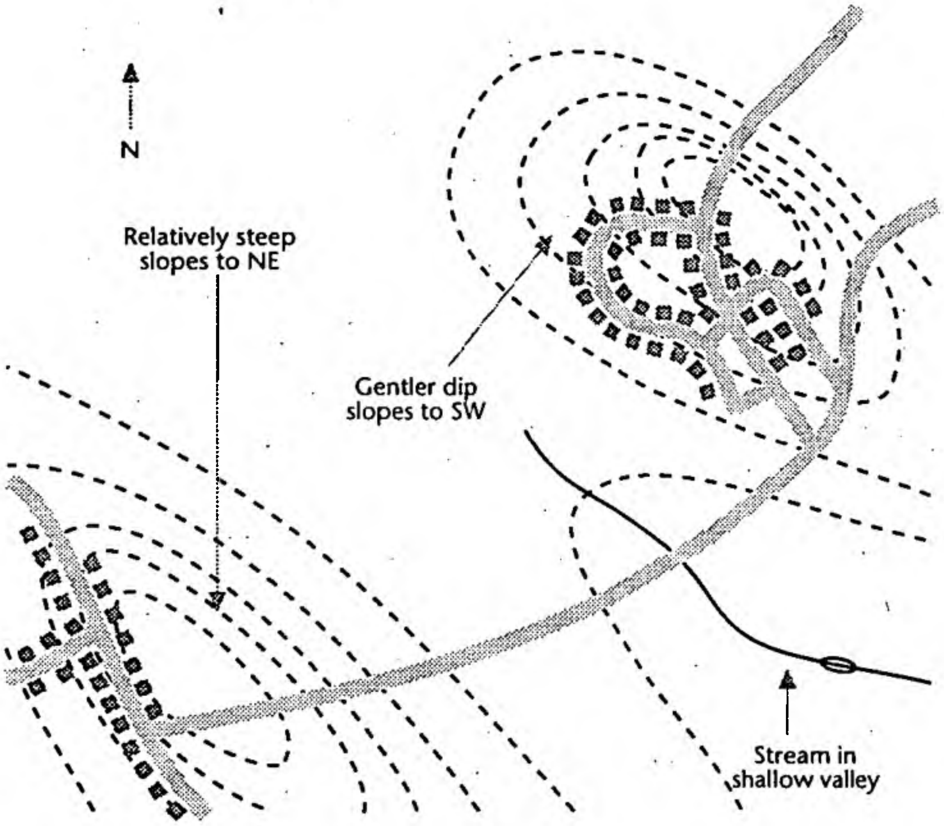
6.31 The shape and orientation of the final landform should reflect its surroundings. Analysis of Ordnance Survey maps and photographs will indicate

- the likely maximum acceptable height of a landraising scheme
- suitable slope gradients
- the overall shape or trend of the local topography.

The new landform will look more natural if it is orientated the same way as the surrounding landform. The shape of the proposed contours should reflect the shape of existing contours near the site: see Figure 6.3. Understanding the regional geology may assist the designer to identify the landform trends, as it will strongly influence the local topography.

[39] See WMP26B, Chapter 6 for more detail on calculating settlement.

Figure 6.3 Character of local topography



Slope gradients

6.32 Under the CDM Regulations, the operator and designer must ensure that the design of the site is intrinsically safe. All reasonable steps must be taken to minimise risks attached to the site during construction, restoration and aftercare. This includes appropriate after-uses on steeply sloping areas which are potentially dangerous to cultivate and maintain.

6.33 Gradients which are 1 in 15 or steeper will reduce the adverse effects of differential settlement, chiefly waterlogged areas in low spots, and remedial action will not be essential. The visual effects of differential settlement will be less noticeable on undulating or sloping sites than on relatively flat sites.

6.34 The designer may wish to create steep gradients in the final landform

- for drama and interest
- to reflect naturally-occurring features.

When considering steep slopes the designer must take the following factors into account.

- Measures for erosion control, particularly on slopes steeper than 1 in 10.
- Steep slopes may not be possible with wastes other than excavation materials.
- If an artificial membrane capping system is to be used, this may lead to soil instability on steep slopes.

6.35 Perimeter screening bunds may be constructed using natural materials which lend themselves to more varied contours. This may enable other parts of the site to be finished to gentler gradients, without affecting the site volume, to reduce the visual impact of the site and permit a variety of after-uses: see Figure 6.4.

6.36 If the proposed landform reflects its surroundings, the site will be potentially suitable for the same agricultural and other land uses as are found on adjacent land. The designer must observe certain maximum and minimum slope gradients, related to drainage and after-use, which are given in Table 6.1.

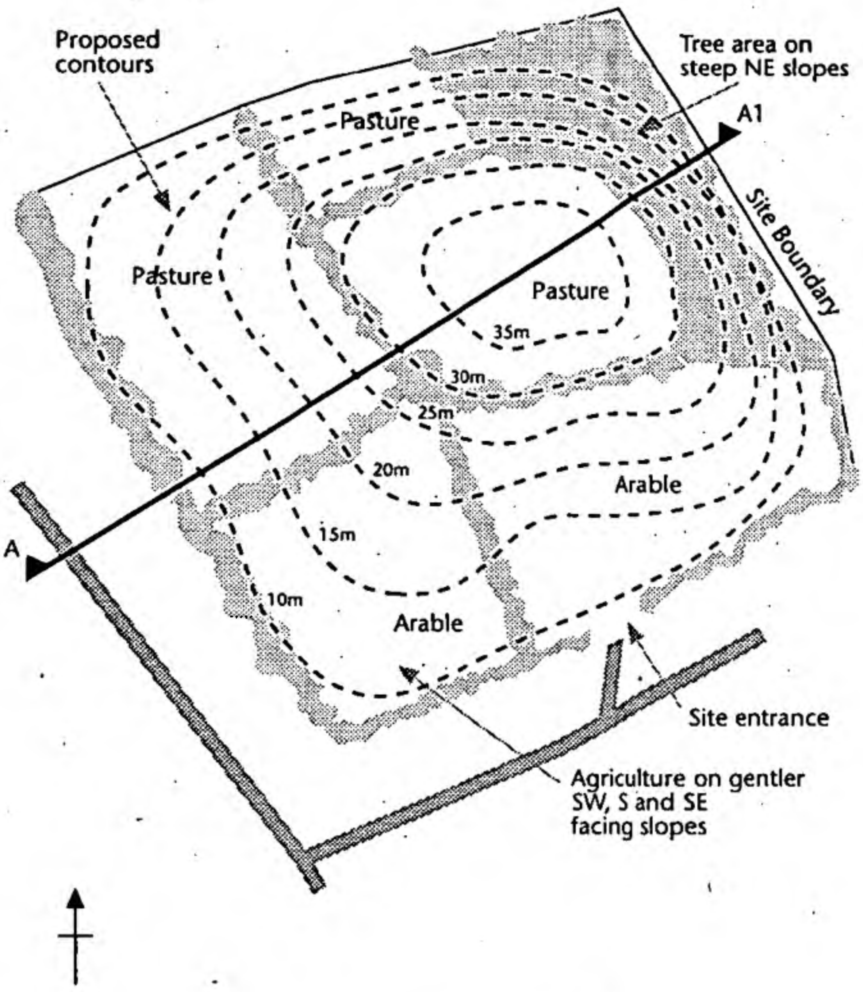
6.37 The designer should consider minimum gradients of 1 in 25 on sites which may be subject to differential settlement. Even in flat areas the final landform should be designed to this slope gradient if possible to

- ► encourage natural drainage
- ► reduce the effects of differential settlement on drainage systems
- ► ensure that field drainage systems on the restored site remain effective.

6.38 The maximum slope gradient which can be safely and effectively cultivated, farmed or managed depends upon the operation being undertaken and the type of machinery being used. MAFF recommend the following maximum slope gradients

- ► arable agriculture - 1 in 8
- ► pasture agriculture and amenity grassland - 1 in 5.

Figure 6.4 Variations in slope gradients



Cross section along A - A1

Table 6.1 Slopes of land in relation to use

Gradient			Significance for land use
Fraction	%	Degrees (to horizontal)	
1 in 1	100	45°	
1 in 2	50	27°	Maximum for downhill use of most forestry machinery (Rowan, Forestry Commission (FC) 1977).
		25°	Maximum for pasture land to avoid soil creep and formation of paths by animals across slopes (Soil Survey of England and Wales, SSEW, 1969).
1 in 3		18°	Maximum for Grade 4 agricultural land (MAFF 1988). Limit for 2-wheel drive tractors with fully mounted equipment. Maximum for uphill use of most forestry machinery (FC 1977).
1 in 4	25	14°	Mean recommended incline for artificial ski slopes (English Ski Council)
1 in 5	20	11°	Maximum for Grade 3b agricultural land (MAFF, 1988), Limit for most machinery used in cereal and grass production including combine harvesters and 2-wheel drive tractors with trailed equipment. Maximum slope for 2-way ploughing.
1 in 8		7°	Maximum for Grades 1, 2 and 3a agricultural land (MAFF, 1988). Suitable for most agricultural machinery but the limit for precision seeding and harvesting equipment.
1 in 10	10	6°	Maximum longitudinal gradient for forest roads (FC).
1 in 40	2½	1°25'	Optimum gradient for drainage channel (MAFF). Maximum lateral slope for playing fields (Nat.Playing Fields Assn.NPFA 1963).
1 in 60	1½	0°57'	Recommended gradient for winter games 1 in 60 - 1 in 80 (NPFA, 1963).
1 in 80		0°43'	Minimum desirable cross fall for cricket pitches (NPFA, 1963).
1 in 200	½	0°23'	Minimum practical fall for piped land drainage (DES 1966).

Note: For agriculture and forestry these are general guidelines which take account of safety. For agriculture the degree of limitation is also influenced by slope form in relation to field boundaries.

6.39 Grass may be established on slopes of up to 1 in 3 providing it is possible for tractors and mounted or trailed equipment to work safely up and down the slope and not turn or traverse across the slope. However this is not recommended. The designer should consider measures to control run-off and erosion on steep slopes, including

- geotextiles
- cut-off ditches and french drains
- timing of cultivation and seeding works so that grass can establish and form a cover before the winter.

6.40 The use of tracked machinery is recommended on slopes steeper than 1 in 3 or 1 in 4. The designer should use these slopes for trees and shrubs, rather than agriculture or managed amenity grassland. Unless they fulfil a particular landscape design objective, slopes steeper than 1 in 3 should be avoided because they

- generally appear unnatural
- are difficult to cultivate and seed
- are difficult and costly to maintain.

6.41 Localised use of steeper slopes, giving a series of broadly spaced terraces (see Figure 6.5), may reflect natural features and increase void space. The steep slopes may be planted with trees and shrubs to form wide field boundaries. The height of these terraces should be related to the depth of landfill lifts, generally approximately 2 metres. With the exception of inert sites, the designer should avoid complex landforms because they lead to

- operational problems
- increased costs of landfilling, gas control and drainage.

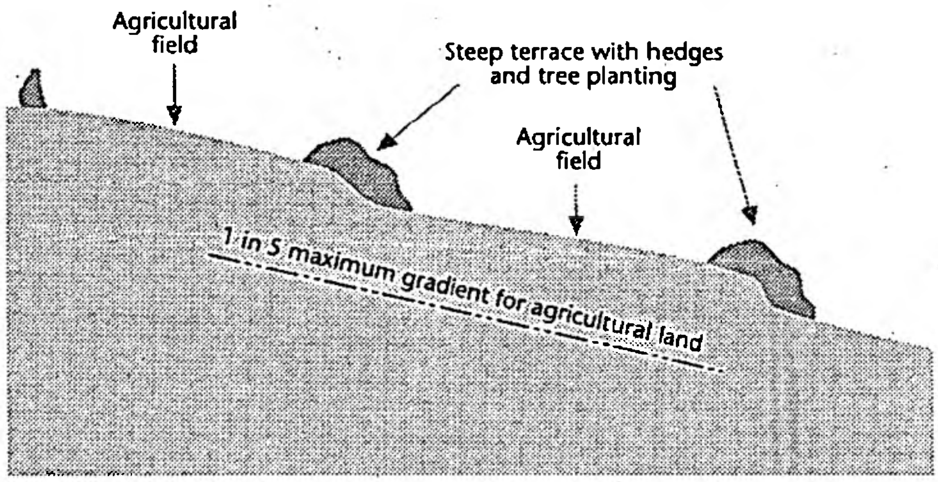
Specialised techniques, including the use of geotextiles and hydraseeding, will be necessary to cap and restore very steep slopes.

Hydrogeology

6.42 The designer should be aware that the level of groundwater will affect the opportunities for landform design[40]. The sensitivity of the aquifer is an important consideration in landfill construction and operation, and may also affect restoration and aftercare design.

[40] See WMP26B for information on groundwater protection and landfill design, and the NRA Policy and Practice for the Protection of Groundwater.

Figure 6.5 Terraced slopes



6.43 The void space may be increased by excavating the area to be lined. The suitability of this approach and the depth of excavation will be determined by

- the nature of the underlying strata
- the depth of the groundwater.

6.44 If he wishes to adopt this approach the designer must investigate these two aspects at an early stage of design. He must consult the Environment Agency and refer to their groundwater protection policy to ensure that excavation proposals

- meet the approval of the Environment Agency
- do not risk the safety and integrity of groundwater resources, particularly near groundwater abstraction points.

Hydrology

6.45 The designer must take account of any surface watercourses on or adjacent to the site[41].

6.46 Drainage ditches and natural streams should be diverted around the site or culverted beneath the fill area during the operational life of the scheme. The designer should consider reinstating these during restoration and aftercare

- to assist with surface drainage
- to provide water or wetland features at the perimeter of the site.

[41] See WMP26B, Chapters 6 and 8 for engineering aspects.

Soil availability

6.47 The availability or otherwise of topsoil and subsoil on the site or in the locality is a critical design consideration. The feasibility of the proposed after-use is heavily dependent upon the availability of sufficient, suitable soil for restoration. This is addressed in more detail in Chapter 8.

6.48 The characteristics of the available soils may also influence the design of the site by affecting the potential after-uses.

- Agriculture will be most successful on fertile, well-structured soils which are moderately well-drained.
- Managed amenity grassland requires a fertile soil to support a vigorous grass sward which will withstand intensive recreational use.
- Woodland and wildlife after-uses can establish successfully on less fertile soils, with wildlife after-uses being more successful on infertile soils.

Interaction with pollution control systems

6.49 The operator must consider the effect of pollution control systems, particularly landfill gas extraction systems, on the proposed after-use at the restoration and after-use design stage. This is considered in more detail in paragraphs 6.78 to 6.113. The following key aspects must be considered.

- The suitability of the proposed contours for gas and leachate control.
- The size and location of tree and shrub areas and the width and orientation of hedgerows as they affect the requirements for the gas pipe network.
- Access arrangements for both agricultural operations and pollution control systems must be co-ordinated.

6.50 The management and treatment of leachate and surface water drainage must also be considered with restoration design. It is often possible to integrate these with restoration design by creating water and wetland features such as retention ponds, reed beds and surface watercourses.

Landscape design considerations

6.51 High quality landscape design is important in creating an attractive, sustainable restored landfill site. It will

- ► enable the restored site to blend into its surroundings and make a positive contribution to the landscape quality of the area
- ► provide a suitable landscape setting for the proposed after-use
- ► recognise long term management and maintenance requirements.

6.52 Landscape design features should also be used to reduce the visual impact of the site by

- ► landscape features such as screening mounds and tree planting
- ► restoring and planting completed phases to screen operational ones.

6.53 The objectives of landscape design are

- *long term* - landscape integration and full realisation of the after-use potential
- *short term* - initial landscape works and screening to improve the external appearance of the site.

6.54 The designer can achieve landscape integration by creating visual links with adjacent features through the planting design, by

- ► continuing existing hedgerows across the reclaimed site
- ► extending adjacent woodland into the landfill site using the same mix of species
- ► replicating small scale features such as rock outcrops, localised steep embankments, raised field boundaries and stone walls.

6.55 The landscape design will also take account of public rights of way which cross the site, either on permanent diversion route agreed with the local authority, or reinstated on the original route when landfilling has finished. These routes should be integrated into the landscape design.

6.56 Different after-uses have individual landscape characteristics which should be included in the design. These features may be identified by studying the landscape which surrounds the site, and other areas of similar land use. The next sections describe landscape features for the following after-uses

- ► agriculture: paragraphs 6.57 to 6.59
- ► amenity tree planting and nature conservation: paragraphs 6.60 to 6.67
- ► open space and recreation: paragraphs 6.68 to 6.72
- ► hard end uses: paragraph 6.73.

Table 6.2 summarises these features.

Agriculture

6.57 Agricultural land is generally typified by a field pattern, giving a fairly structured landscape with fields divided by hedgerows, walls or fences. The restored site should reflect local patterns and boundaries to integrate the site into the agricultural countryside.

- Many agricultural landscapes have been impoverished by hedgerow removal: landfill restoration can improve the landscape quality, in the long term, by re-introducing the hedgerow system.

6.58 By replicating the existing field pattern, local farming practices can be encouraged after restoration. Existing hedge lines, previously truncated by the landfill development, should be continued over the restored site for long term landscape integration: see Figure 6.6.

Table 6.2 Landscape design features related to after-use

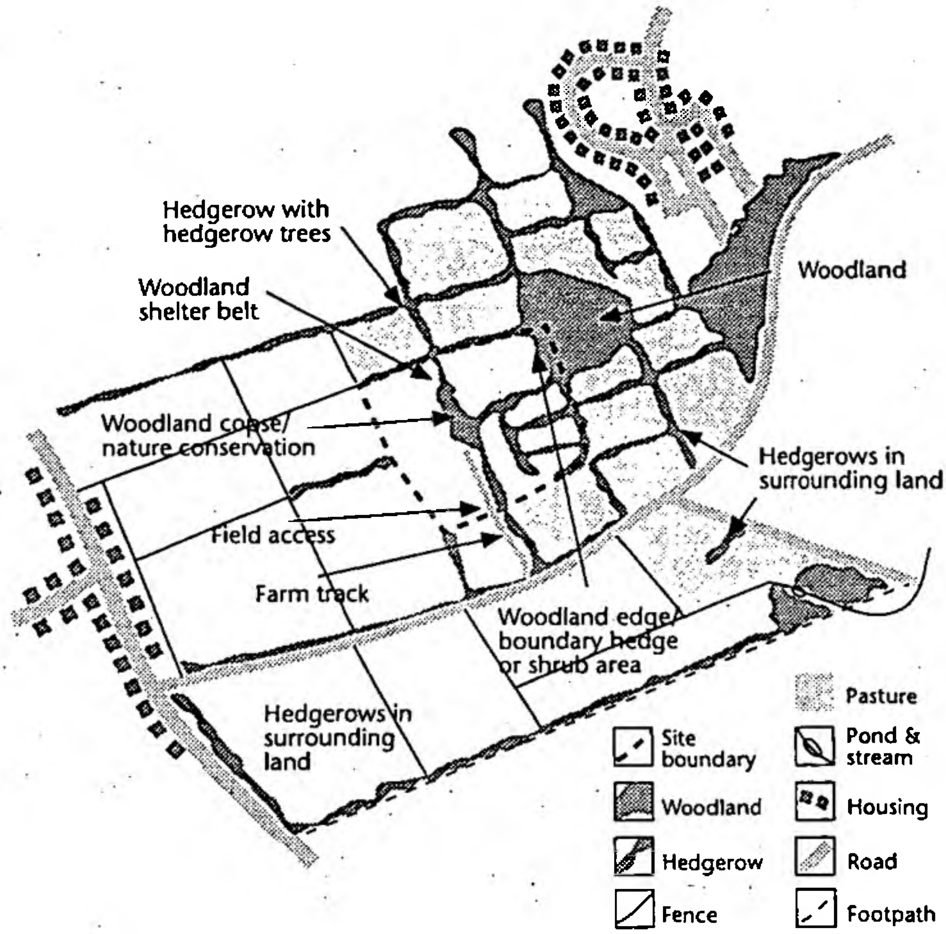
After-use	Landscape design features
Agriculture	Field pattern, hedgerows Farm access tracks Drainage ditches, water supply Woodland shelter belts and copses Small areas for wildlife
Woodland	Woodland, scrub, open grassland areas Woodland glades, rides Access tracks, footpaths
Amenity and nature conservation	Wildflower meadows Heathland Rock features Streams, ponds, wetland areas
Open space and recreation	Specific gradient requirements Structure and screen planting Water features Wildlife areas Footpaths, cycleways, vehicular access tracks

6.59 Other features of agricultural landscape include

- farm access tracks
- ditches and small streams
- woodland shelter belts and small copses
- small areas in field corners and woodland edges of wildlife interest.

The designer should incorporate these into the landscape design to give the site, in time, a more natural appearance.

Figure 6.6 Landscape integration



Amenity tree planting and nature conservation

6.60 Amenity tree planting and nature conservation allow the landscape design to be more flexible. The designer should use this to minimise potential conflicts between aftercare and environmental protection. The following paragraphs describe the landscape features associated with areas of tree planting and nature conservation.

Wild flower meadows

6.61 Open grassland areas, which will not be managed for productive agriculture, may be irregular in shape and size and surrounded by shrub and tree planting. The site could be designed for

- increased variety of plant and animal species
- attractive visual appearance
- public access and enjoyment.

The designer should include paths for public access, with simple bridges or boardwalks to cross streams and wetlands if appropriate. Public access should be limited to non-operational areas, and given careful consideration on phased landfills if parts of the site are still active. Vehicular access must be provided for on-going maintenance.

Heathland

6.62 Heathland, and other upland landscapes are characterised by grassland with heather and low shrubs. Other features may include

- groups of rocks exposed at the surface
- stone walls to subdivide field areas.

If the site is a former rock quarry, the designer should consider retaining some exposed rock faces, within the constraints of public safety, to create added interest in the restored site. The design must meet the operational requirements of access, waste containment (lining and capping), final gradients and drainage.

Amenity woodland

6.63 Tree planting must be carefully designed and programmed to avoid conflict with engineering systems on new landfill sites: see Chapters 2 and 10. Mass tree planting is more appropriate on sites which have taken predominantly inert wastes. Optimum use should also be made of the site perimeter and areas which have not been landfilled. Even small areas of tree and shrub planting can become wildlife habitats.

6.64 Amenity woodlands may be planted with a variety of tree and shrub species, preferably indigenous, to give different heights of growth and density of cover and shade. Alternatively, a limited number of species, such as oak and birch, may be planted to allow colonisation by locally indigenous plants. Shrubs may be planted around the edges of mass tree planting to give a woodland edge effect, reflecting semi-natural and established woodlands. Small clearings in planted areas also give a wider variety of habitats and more wildlife interest, and may be designed to accommodate gas and leachate systems.

6.65 In larger areas of tree planting, access tracks should be included for maintenance. These can add to the wildlife interest by providing different conditions for plant growth. These tracks may be designed to allow access to wells and pipework for monitoring and maintenance. In the longer term they will also become firebreaks.

Wetlands

6.66 Undulating contours, which may result from settlement, will give low areas which may retain rain water. These may become water features and wetland habitats which will contribute to the site's landscape quality and wildlife value.

- The siting and construction of ponds and streams on capped sites must be very carefully considered.

- The designer should not locate these features over the cap, but alternatively away from the landfill area.

6.67 Ponds should be designed with gently shelving banks to allow water margin plants to establish, and to enable birds, frogs and newts to get in and out of the water. If ponds are large enough, islands located well away from the pond edges will become wildlife havens, protected from predators and people. If possible ponds should be lined with puddled clay or a membrane so that they contain water throughout the year (see Figure 6.7).

Open space and recreation

6.68 The landscape design will depend on the activities to be carried out on the restored site, which may range from organised sports such as football to passive recreation. The neighbourhood may need a site for a specific activity such as motorcycle scrambling, golf or horse riding.

- The designer must pay particular attention to the location of pavilions and other buildings.

  - ► On new sites they should be on non-landfilled areas.
  - ► On closed or existing sites there may be considerable risks attached to locating buildings or structures on any part of the site: see Chapter 12.

6.69 Measures to prevent or discourage vandalism and fly-tipping, and to ensure public safety, should be considered.

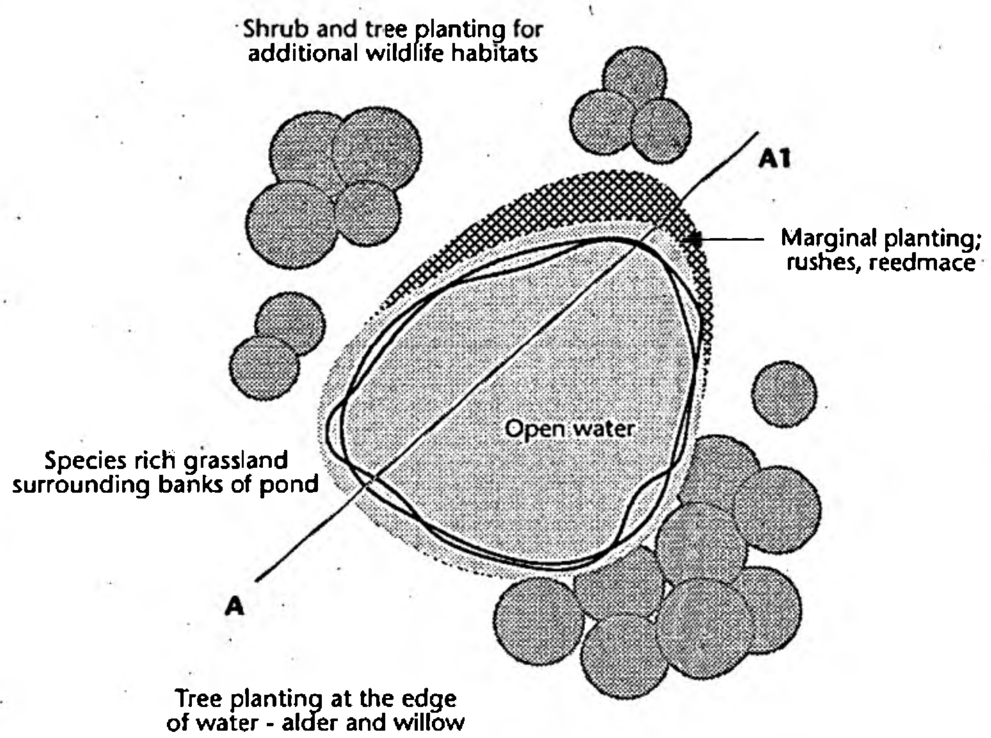
6.70 The landscape design must suit the needs of the proposed after-use, in terms of

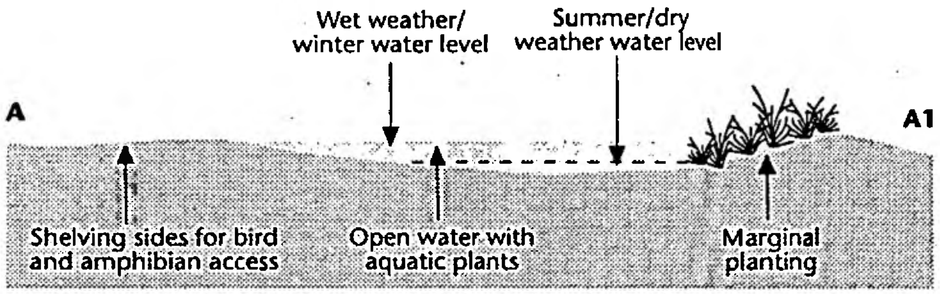
- ► contours
- ► soil depth and drainage
- ► planting design
- ► access arrangements.

The designer may need to seek specialist advice for the detailed design of sports pitches, golf courses or other activities.

6.71 The designer should include structure planting on passive recreation sites to give interest and shelter, especially on large exposed sites, to encourage public use. He should consult the planning authority and local residents so that the design reflects the needs of the local community. He may be able to use the liaison group, if one exists (see Chapter 2), to involve the local community in the landscape design. This may encourage support for the scheme, especially if the site is unsightly, dangerous or used for unwelcome activities such as fly tipping.

Figure 6.7 **Wildlife pond**





6.72 Areas for wildlife, including ponds and wetland, will make the site more acceptable to local residents. Public access should be provided by paths and cycleways. The operator may consider an access agreement (made between the landowner and the local authority under the National Parks and Access to the Countryside Act 1949), to open the land for public access, either as a whole or along specific routes. This must be investigated at the design stage if permissive rights of access are being considered.

Hard end uses

6.73 On hard end use sites the landscape element will include

- screening
- landscaped areas surrounding the development.

The designer should include additional soil depths in landscape areas to increase the range of species which can be planted. The character of such areas is likely to be more ornamental than for other after-uses and this will influence planting design.

Landscape design consideration for possible future changes in after-use

6.74 Landfill developments may span many years, and the designer must take into account foreseeable future changes in land use. The design should not limit future after-uses by

- not fulfilling the after-use potential of the site
- inappropriate contours or planting.

Landfill phasing design objectives

6.75 The *design* objectives of landfill phasing are to

- minimise the visual impact of the site on local communities
- minimise the impact on ecology and landscape quality
- reduce initial site disturbance
- minimise the duration of disturbance on each part of the site
- maximise areas for early tree planting on the site.

6.76 To fulfil these objectives the designer must carry out assessments to identify

- *on-site features* which will be affected by the proposals
- *sensitive receptors* such as residential areas and important view points.

This information will enable the phasing so that each phase is screened either by screening mounds or completed restored phases.

6.77 The phasing proposals[42] and the landscape design should be developed together so that features such as field boundaries and changes in land use can be related to operational phases.

[42] See WMP 26B for more detailed information on phased landfills.

Design considerations for engineering systems

6.78 The key design considerations for engineering systems are

- the protection of the pollution control systems including
    - capping layer
    - leachate and landfill gas systems
    - fixed monitoring points (piezometers) for settlement, groundwater quality, leachate and gas.
- The long term requirements for the stabilisation of the fill.
- Integration of the engineering systems with aftercare and after-use.
- The long term screening of the operational site compounds and fixed plant - gas engines and flares, leachate treatment plant, garages and workshops.
- Health and safety considerations[43].
- Site security, fences, gates, protection against vandalism.

6.79 Table 6.3 summarises the design considerations for engineering systems which relate specifically to restoration and aftercare. The following section describes the restoration design considerations for

- capping system: paragraphs 6.80 to 6.83
- accelerated stabilisation: paragraph 6.84
- landfill gas systems: paragraphs 6.85 to 6.101
- leachate collection, treatment and disposal: paragraphs 6.102 to 6.111
- operational site compound and ancillary facilities: paragraphs 6.112 to 6.114.

Table 6.3 Design considerations for engineering systems

Engineering system	Design consideration
Capping layer	Gradients no steeper than 1 in 5, or gradual changes in gradient. Minimum gradients of 1 in 30 for surface water run-off. Minimum soil depth of 1 metre, increasing to 1.5 metres in tree areas, to prevent damage and desiccation (see Chapter 8 for plant growth soil requirements).
Gas monitoring boreholes	Locate along field boundaries and in non-agricultural areas wherever possible.
Gas control system	Co-ordinate the gas system design with the landscape and restoration design. Consider non-agricultural after-uses, or include non-agricultural areas such as wide hedgerows, access tracks, shelterbelts, woodland and nature conservation areas. Integrate these features with the gas control system. Locate horizontal pipework above capping layer with collection mains in stable (non-filled) ground if possible. Locate wells along field boundaries and in non-agricultural areas wherever possible.
Engineering system	**Design consideration**
	Select gas system with design features which are most appropriate to the proposed after-use; ► lay pipework so that plant and machinery can run over it without causing damage ► lay pipes in 300 mm mineral non-soil layer above capping layer ► lay pipes below depth of field drainage systems, (600 mm below the surface).
Gas Compound	Agree compound size and location with landfill gas specialists at the design stage. Integrate the compound in the landscape design. Include mounding and planting for visual and noise screening in the design of the compound for long term screening and integration into the post-closure landscape and after-use. Screening mound slopes should not be too steep to make maintenance difficult or to bring vegetation too close to the flare, or gas engine radiator units. The compound should not be located in an area where trees would be affected by the heat from the flare stack. Choose lower growing shrubs for more effective screening.

Table 6.3 (cont) Design considerations for engineering systems

Leachate collection system	Locate collection sumps and pumping manholes at field boundaries, along access tracks and in areas which will not be intensively managed for agriculture or recreation.
Leachate treatment compound	Combine with gas compound if possible to simplify screening design. Screen with mounding and shrub planting. Ensure suitable access and manoeuvring space for road tankers if necessary or likely in the future.
Operational site compound/ ancillary facilities	Screen workshops, garaging, heavy plant, civic amenity skips etc from external view by careful siting and screening with mounds and/or fencing. Keep planting simple and appropriate to the harsh environment of the site entrance and compound.
Man entry chambers	Vehicular access may be required. May need to be of a considerable size, working area around chamber required.

Capping system

6.80 The cap may be constructed of clay, synthetic membrane, purpose-designed geotextile or a combination of these[44]. Many older sites are not capped, and landfills which have accepted inert wastes may not have a capping requirement.

6.81 The designer must be sure that the restoration design takes account of the requirements of the cap. These are

- gradients suitable for cap construction to full quality assurance standards
- sufficient soil depth to protect the cap from damage by
  - desiccation
  - cultivation and drainage works.

6.82 Steep slopes or abrupt changes in gradient may cause construction difficulties in laying a compacted clay cap, making it difficult to achieve full compaction of the clay.

6.83 Preferred minimum soil depths for the protection of the cap and establishment of vegetation are given in Chapter 8. Where soil is scarce, the operator may wish to discuss restoration using shallower soil depths with the planning authority. In this event he must demonstrate that this will not compromise restoration standards or after-use.

[43] See WMP26B, Chapters 8 and 9.
[44] See WMP26B, Chapter 10.

Accelerated stabilisation

6.84 The decision to operate the site for accelerated stabilisation will affect operational practice and restoration programming, rather than restoration design. Interim restoration will become an important part of the reclamation strategy, and the restoration design must reflect this. The restoration design should show

- the restoration programme
- interim restoration proposals
- establishment of long term landscape features.

Table 6.4 Components of landfill gas systems

Cmponent	Location	Function	Features
Migration monitoring boreholes.	On site perimeter outside landfilled area, 30-50m spacing (or closer).	Identify environmental liabilities from gas. Monitor performance of control system.	Borehole terminates in small cap/metal box just above ground. May be connected together with telemetry cables for remote sensing.
Passive gas vents/trenches.	Usually near edges of landfilled area on older sites in rural locations with low gas flows.	Venting landfill gas (in small quantities).	Vertical above ground pipe 1.5 - 2 m (up to 4 m) high. Rubble-filled trench.
Active extraction for migration control.	Well spacing 30-40m intervals at edges of site.	Pumped extraction of gas to prevent migration.	Vertical wells terminating at or above ground level. Connected below ground via horizontal pipes leading to gas compound. May be regular grid pattern or linked to gas main running in stable ground round perimeter of site or phase.
Active extraction for utilisation.	Over whole site well spacing 40-80m intervals, mainly in centre of site.	Pumped extraction of gas for energy.	As above.
Gas compound.	Outside landfilled area suitable for access, maintenance and export of energy.	Gas flaring, generation of electricity, pumping and monitoring.	Security fencing, gas flare stack, pumping equipment, dewatering points, gas engines or turbines, electricity generating equipment, transformers, control equipment.

Landfill gas systems

Components of the gas control system

6.85 The design team must work together to integrate the restoration and landscape design[45] with the gas system design. For this process to be successful each team member must appreciate the objectives of and constraints upon the others: the landscape designer should therefore be familiar with the principal components of the gas system, which are outlined in Table 6.4[46].

6.86 The design of the gas system will depend upon

- the types of waste which the site is to accept
- the age of the site.

Landfill gas systems and restoration

6.87 This section summarises the potential effects of the gas system on after-use, restoration and aftercare so that the designer can include features in the design which

- promote the long term efficiency of the gas system
- minimise effects on after-use[47].

The design of the gas system, in particular

- the siting and frequency of gas wells
- the depth of horizontal collection pipework

will profoundly affect restoration and aftercare, and the suitability and viability of after-uses, particularly agriculture: see Chapter 9.

6.88 On older sites the active extraction system may be installed on part of the site only, in response to gas migration. Such a system may need to be extended or modified

- as the site is completed
- as later areas of landfilling begin to produce gas
- to convert passive vents to an active extraction system.

[45] See Appendix E for more detail on gas system design and restoration.
[46] See WMP26B, Chapters 6 and 9 for more detail on landfill gas control.
[47] See Appendix E for more detail on gas system design and restoration.

6.89 The principal design factors to be considered in order to minimise potential conflicts, and to achieve effective gas control and sustainable after-use, are

- i choice of after-use
- ii design of the gas system
- iii design of the gas compound.

These are described in the following paragraphs.

i Choice of after-use

6.90 Careful selection of after-use is essential. On sites where gas control is required the operator should, if possible, consider the choice of after-use in the light of the following.

- Agricultural areas require maximum use to be made of the land for cropping, and above-ground gas equipment may severely reduce productivity. Gas wells in fields may be damaged by agricultural activities, and should be located on field boundaries wherever possible: this may not suit the gas control system design.
- Amenity and nature conservation after-uses allow a more informal landscape design to be adopted. Wells can be located in areas which will be intensively managed. Tree planting should be delayed until after the initial settlement period: see Chapter 10.
- Amenity and nature conservation after-uses do not require frequent maintenance: this reduces the potential for damage to maintenance machinery and the gas system.
- Trees and shrubs will screen manhole chambers making them less noticeable after restoration.

ii Design of the gas system

6.91 The operator should provide sufficient detail about the gas control system at the design stage to enable the regulators to evaluate the potential effects of the system on the after-use. The design should be flexible enough to incorporate newer technologies as they come into use.

- On both new and existing sites, the gas control system must be designed to provide **long term** environmental protection.
- On a phased landfill the gas system for the whole site should be designed from the outset, assuming a programme of staged installation.
- The operator should avoid designing a temporary or partial system in the expectation of extending it later as this is likely to be both disruptive to restoration and expensive to instal.

6.92 Having due regard for site safety and environmental protection, the designer should consider siting monitoring boreholes and gas wells

- **in areas which will not be intensively managed during aftercare**
- **along farm access tracks and field headlands**
- **along woodland rides or firebreaks.**

These locations permit easy access for monitoring and maintenance, as well as protecting the above ground parts of the system from damage during aftercare.

6.93 Gas control systems differ in their detailed design features and general arrangements and one system may be more suited to the site than another.

- **When the designer selects a system, he should have the proposed after-use in mind, so as to minimise the impact of the system on aftercare.**

The pipework should be located below the depth of cultivations and land drainage systems, preferably in a mineral layer comprising non soil material above the cap.

6.94 The designer should consider separating the vertical well from the well head valve gear and monitoring equipment: see Figure 6.8. This design

- places the wells where they are needed for gas extraction and site safety
- locates the above-ground features in areas remote from the well
- reduces the impact of the gas system on the after-use.

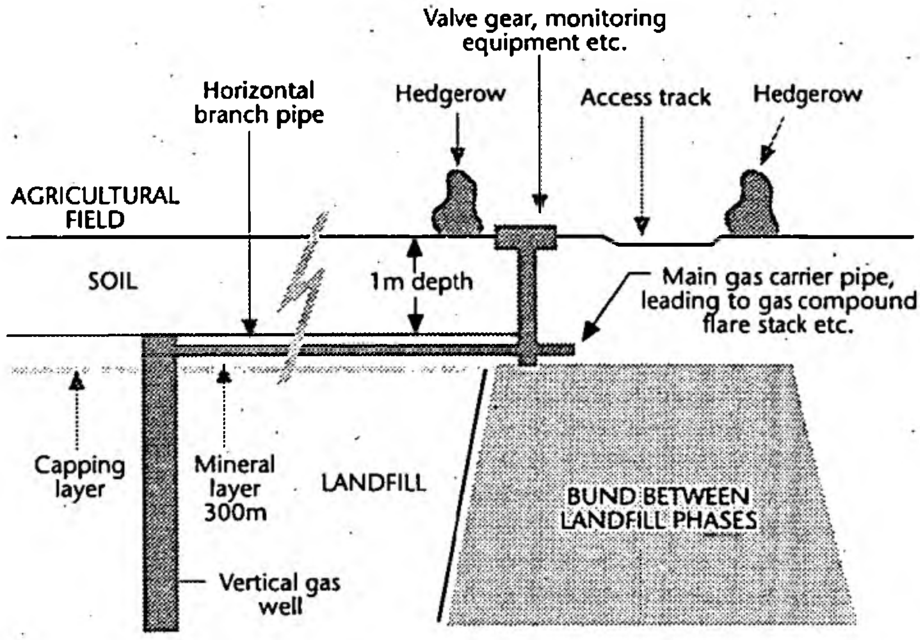
The vertical well should extend above the capping layer, ideally into a mineral, non-soil layer. If interim restoration (see Chapter 7) is carried out, using a reduced soil depth for the first 3 to 5 years, the vertical portion of the well will remain accessible for repairs and monitoring. This also allows the operator time to demonstrate the performance of the control system before full soil replacement.

6.95 Choice of materials for the gas system is also important[48]. The designer must make a proper assessment of the required pipe strengths, relative to the aftercare activities and after-use.

- Medium density polyethylene (MDPE) pipes and fittings of a type used by British Gas are suitable because
  - they are resilient and can withstand traffic during restoration and aftercare particularly if covered with 1 metre of soil to protect them
  - they can withstand most of the loads imposed by settlement of the landfill
  - they are available in bright colours (e.g. yellow) which are easily visible during maintenance and aftercare excavations.
- Steel pipework systems should only be used above ground.

[48] See WMP 26B for more information on gas system design.

Figure 6.8 Remote landfill gas wellhead



The depth and specification of the pipework must withstand soil spreading and agricultural machinery which is used during restoration and aftercare.

iii Gas compound

6.96 The design team must jointly agree the best location and dimensions for the gas compound. It should be included in the landscape design. The location of the gas compound should be selected with regard to the following.

- Technical constraints, such as gas flow and the pipe network, which are dependent upon the finished gradients for good performance.
- Whether the compound will be used for power generation (location of electricity grid connection or energy user) or flaring (visual impact) or both.
- Access for service and construction vehicles, power supply and other services.
- Area and phases of landfill - the compound should not be located over landfill.
- The compound is virtually permanent and cannot be moved easily.
- Location of sensitive receptors such as residential and recreational areas which may be affected by appearance and noise.
- The after-use of the site.

6.97 The designer must be aware that the compound will remain on site after restoration. Most sites will be restored to non-industrial uses such as agriculture, amenity, recreation and nature conservation, where the compound will be an incongruous development. He should give careful consideration to screening, building materials and choice of security fencing.

6.98 In order to avoid damage to vegetation and reduce the risk of fire, the compound should not be sited close to trees. Earth mounds should be designed for both noise and visual screening, and sufficient space must be allowed to give internal gradients no steeper than 1 in 2: this will ensure that vegetation will not be too close to the flare stack or gas engine radiators.

6.99 The designer must consider the height and appearance of the units within the compound. The highest unit is likely to be the flare stack, and its design will vary according to the manufacturer.

- Some stacks are designed to be an attractive feature in themselves and the designer should therefore consider whether they should be screened from view or accepted as a focal point.

The designer's decision is conditioned by the proposed after-use:

- ► where the site is to be returned for amenity, recreation or hard end uses a feature flare stack may be appropriate
- ► for agriculture, woodland or nature conservation after-uses the flare stack will be intrusive and should be screened.

6.100 The lower compound units such as gas engines, buildings, pipework, parked vehicles, security fencing are unsightly and should be screened whatever the after-use. Mounding to a height of at least 4 to 5 metres will be necessary. The appearance of the mounds should be softened and improved with planting; this will also give increased screening in the longer term. Lower growing shrubs should be chosen which give more effective screening.

6.101 If the gas compound is to be removed when no longer required, the screening mounds and planting may also have to be removed at that time. Most shrubs become over-mature after about 15 years and can be removed without serious loss of landscape value. Trees, on the other hand, will be an attractive feature after 15 years, and local residents may object to their removal.

Leachate collection, treatment and disposal

6.102 The key elements of typical leachate systems are summarised below, so that their restoration and aftercare design requirements can be more clearly appreciated. On sites which are engineered for accelerated stabilisation the leachate system may include recirculation pipework[49].

[49] See WMP 26B for more information on leachate recirculation.

Components of the leachate system

6.103 The key components of the leachate collection, treatment and disposal system are as follows[50].

- Fixed leachate monitoring points within each landfill phase, retained until the certificate of completion is issued (the gas control system should not be relied upon for leachate monitoring).

- Leachate collection sumps from which the leachate is removed by pumping in vertical wells or inclined side slope risers, or which are gravity drained.

- Submersible or eductor pumps housed in manholes at the leachate wells or side slope risers.

- Leachate pipework system (or rising main) to take leachate from the collection manholes to the treatment plant, lagoon or off site.

- Leachate treatment plant, usually in a secure compound which may house open, lined lagoons, or closed modular treatment containers.

- Disposal either direct to sewer, by road tanker or (when fully treated) via reed beds to local watercourse.

The treatment process and method of disposal must be agreed with the regulators.

Leachate system and restoration

6.104 The influence of the leachate treatment system upon restoration and aftercare is less extensive than that exerted by the gas control system.

- There is some flexibility in the location and frequency of the leachate monitoring points, collection sumps and associated manholes.

The design of the system, and the leachate treatment compound will affect restoration and aftercare. These aspects are considered in the following paragraphs.

i Design of the leachate system

6.105 The design team must liaise so that an effective leachate system can be incorporated into the restoration design without seriously affecting aftercare operations or the after-use. This may be achieved by

- **locating leachate monitoring points and pumping manholes along field boundaries and access tracks wherever possible, using areas which will not be intensively managed for agriculture or recreation.**

Submersible leachate pumps will need a power supply, usually mains electricity: this underlines the need to locate these in areas with easy access to services.

[50] See WMP26B Chapters 6 and 9 for more details on leachate systems.

6.106 The leachate collection equipment is put in place from the commencement of landfilling; extensions to the system are not likely to be required (cf. gas control systems). If the system has been installed correctly, the efficiency of the leachate pipework system is less likely to be affected by settlement than the gas pipework: it is therefore less likely to require replacement (see Chapter 14). However, rising mains (like gas mains) should, if possible, be located in stable ground which will not be subject to settlement.

6.107 The restoration design should allow access to the monitoring points and leachate extraction pumps for light vehicles.

ii Leachate treatment compound

6.108 The leachate treatment compound will remain until the certificate of completion is issued. The design team should agree the most appropriate location and access arrangements.

- Like the gas compound, it is likely to be an incongruous development in most after-uses, requiring screening with earth mounding and shrub planting.

6.109 The location of the leachate treatment compound will be subject to similar factors as the gas compound. These are

- technical constraints such as gradients and the collection pipe network
- access for service and construction vehicles, including articulated road tankers
- permanent location which is not over landfill
- opportunity for screening the compound from residential and recreational areas
- after-use of the site.

6.110 The units within the leachate compound are not as high as those in the gas compound, with modular systems being 2.5 - 3 metres high: screening will not need to be as high or as extensive. The leachate treatment and gas control equipment may be located in the same compound to simplify screening and planting arrangements.

6.111 The design of screen mounding should take account of the possibility of using *biotechnology* (reed beds) to give the final polish to treated leachate before discharge to stream[51]. Reed beds may be designed as a wetland feature and may develop considerable wildlife interest.

[51] Any such discharge will require consent from the regulators even after the certificate of completion has been issued.

Operational compound/ancillary facilities

6.112 The requirements of the operational compound must be considered at the design stage.

- Its location may be dictated by access off the highway, but the waste reception facility may be separated from workshops, civic amenity skips, garaging and staff facilities so that these elements can be more effectively screened.

6.113 The operational compound may not be required after landfilling has finished, or it may be possible to greatly reduce its size. Unless the site is expected to be operational for several years, screening may be temporary, and fencing or soil mounds may be most appropriate.

- Planting shrubs and trees around the compound must be carefully considered: they may only be in place for a few years before being removed when the compound is restored.

6.114 Entrance landscaping should fit in with the landscape design of the whole site; and plants to be used in the compound or at the site entrance should be carefully selected.

- Semi-ornamental species often look incongruous and do not thrive in the harsh environment of the site entrance

- Thorny shrubs collect windblown litter which is unsightly and difficult to remove and becomes unsightly

- Plants which are close to the roadway are likely to be damaged by vehicle wheels.

It may therefore be more appropriate not to plant trees and shrubs inside the compound, and to confine any landscaping to grass which is easily maintained.

Landscape proposals adjacent to the compound and at the site entrance should be designed so that the compound can be removed and restored with minimal change to the planting.

Chapter 7

Preparation of restoration working plan

Introduction

7.1 This chapter sets out the skills and steps necessary to plan the restoration and aftercare works on site. It assumes that

- the choice of after-use has been agreed: Chapter 4
- all the necessary assessments have been undertaken: Chapter 5
- the design process has been completed: Chapter 6.

7.2 It describes the preparation of the restoration working plan, which is a *working document* setting out the strategy and programme for restoration and aftercare.

7.3 The restoration working plan forms part of the site manual and is included in the planning and waste management licence applications.

7.4 This chapter considers

- phased restoration: paragraphs 7.14 to 7.17
- interim restoration: paragraphs 7.18 to 7.25
- the effects of operational practices on the timing of restoration: paragraphs 7.26 to 7.45
- reclamation of old, existing sites: paragraphs 7.46 to 7.61
- restoration and aftercare contract management: paragraphs 7.62 to 7.79.

The necessary skills

7.5 When landfill operations have finished the project team will become responsible for

- restoration and aftercare works on site
- leachate and landfill gas monitoring and control
- post-closure management of engineering systems.

On closed or current sites restoration works on site may directly follow the design process, and the design team be retained to manage the restoration, aftercare and post-closure environmental protection works. On new sites it is unlikely that the same team members will remain throughout its life: the design objectives must form part of the site manual and restoration working plan.

The restoration working plan must be used to

- ► update the restoration design if necessary, and to
- ► implement the restoration and aftercare works on site.

7.6 Implementing restoration and aftercare works on site will require the skills of

- ► soil scientists
- ► landscape architects or designers
- ► drainage engineers
- ► agriculturists, horticulturists and silviculturists
- ► ecologists
- ► land managers.

Two or more of these skills may exist in one person.

7.7 Liaison between project team members and other specialists is essential. They must also liaise with other landfill professionals including civil and mechanical engineers, hydrogeologists, landfill operators and managers, landfill gas and leachate engineers, plant operators, planners and regulators.

The restoration working plan

7.8 A **restoration working plan** (the plan) must be prepared early in the life of the site so that the objectives of the original design are not lost. The plan will form the restoration strategy, giving a comprehensive plan of restoration and aftercare works. It will also be appropriate for existing sites. It will form part of the site manual[52], setting out the following key aspects.

- The programme for restoration.
- Effects on restoration of operational practices such as
  - ► landfill phasing
  - ► landfill gas and leachate monitoring and control
  - ► access for monitoring and maintenance
  - ► accelerated stabilisation.
- The restoration and aftercare works on site.

[52] See WMP 26B for more detail on the Site Manual.

If changes are made to the original restoration and aftercare design or the intended after-use, the restoration team must refer to the site manual for information on

- landfill gas and leachate systems
- structure of the capping layer.

7.9 The plan should include the following documents:

- approved restoration design plans and supporting statement (submitted with the planning application for new sites)
- restoration and aftercare conditions attached to the planning permission and any aftercare agreements, such as a Section 106 agreement.
- management plan forming part of the aftercare proposals or agreement
- additional relevant information, such as the Health and Safety File prepared under the CDM Regulations (if applicable), and approved amendments to the original proposals.

7.10 The operator may prefer to prepare a **two stage plan** which deals with restoration (soil placement) and aftercare (vegetation establishment) separately. The plan should

- identify areas of initial landscaping for perimeter screening
- outline the management procedures for areas within the site boundary but outside the landfill area
- include **interim restoration** of areas which require further engineering works: see paragraphs 7.18 to 7.25.

On new sites the plan should include *flexibility* to enable new ideas and improved technologies to be adopted, and for updating or modifying it due to changing circumstances on site.

7.11 The contents of the plan are given in Table 7.1. They would be addressed at a level of detail which is appropriate to the site's size and proposed after-use. The contents of the plan would be varied for existing sites where sections on phasing may not be relevant.

7.12 Since the plan will form a working document which is likely to span several years, the operator should make a member of staff specifically responsible for

- recording site modifications which affect restoration and aftercare
- recording changes to the restoration and aftercare proposals
- maintaining and up-dating the plan.

7.13 The plan will continue to be relevant throughout the aftercare and post-closure management period: it must be available to site staff and to those responsible for aftercare works on site.

Table 7.1 Contents of restoration working plan

Stage	Section	Content
Stage 1 Restoration	Phasing	Initial/perimeter restoration to improve appearance of site. Phased restoration following landfill phasing
	Timing	Programming restoration works relate to operational practices affecting restoration and aftercare. Interim restoration (if applicable).
	Soil	Soil resources, soil handling, storage, replacement. Acquisition of subsoil and topsoil. Show areas of soil storage on plans.
Stage 2 Aftercare	Vegetation establishment	Cultivation, seeding, planting, wildlife habitat creation.
	Vegetation management	Non-landfilled areas. Restored site during aftercare period and beyond. Integration of post-closure management of engineering systems.

Phased restoration

7.14 The operator should phase landfilling and restoration unless there are compelling practical reasons why it should not be done: for example, on some sites, phased restoration prevents the optimal use of soils and soil-making materials. The advantages of phased landfilling and reclamation are

- minimal disturbance of non-landfilled areas, with parts of the site being retained in their original condition for as long as possible
- minimal disturbance to wildlife on non-active parts of the site
- improved soil handling - soil may be stripped from later phases and directly re-spread on completed earlier phases: see Chapter 8
- phased return of parts of the site to after-use before landfilling is completed
- allows restoration progress and techniques to be monitored, and amended if necessary in the light of site specific experience
- allows monitoring of tree and shrub planting on early phases
- enables replacement wildlife habitats to be established before the original is destroyed allowing mobile species to transfer to safe areas; also allows local plant types to be re-established on the site if required.

7.15 The landfill phasing will be detailed in the restoration working plan, and should include the following.

- Phasing of soil stripping and replacement, based on the landfill phasing (see Chapter 8), balancing the phased restoration design with the best use of soil resources.
- The strategy for managing phases before development and after restoration.
- Landscaping the site perimeter, boundary and entrance to reduce the visual impact of the site from surrounding areas.

7.16 Restoration phases should follow the phases of landfilling[53]. Landscape features such as field boundaries and tree planting should also follow the phasing boundaries to make aftercare and long term vegetation management easier.

7.17 The operator should consider temporary greening of those parts of the operational area which will not be used for some time, but which are visible from outside the site. This entails establishing a grass cover on the surface material. It will

- ► improve the appearance of the site
- ► control rain water run-off
- ► reduce windblown dust
- ► prevent erosion of non-vegetated surfaces.

Interim restoration

7.18 Interim restoration is recommended to minimise the difficulties which are frequently encountered during aftercare resulting from gas control works and other operational practices. It has five main functions:

- ► to enable higher standards of restoration to be achieved
- ► to reduce soil damage
- ► to improve the site's appearance while frequent work on the engineering systems is needed
- ► to protect the cap and reduce rainwater infiltration through the soil
- ► to control surface water run-off and erosion.

Interim restoration delays the commencement of the aftercare period until after the period of most intense pollution control activity, by which time the disturbance to restoration and aftercare on site will be reduced.

7.19 The operator must consider interim restoration as part of an overall programme of restoration developing with site operations and environmental protection leading to a sustainable final restoration.

[53] See WMP 26B for detail on landfill phasing.

7.20 Interim restoration may be appropriate in the following situations.

- Where a new gas control system will be installed, or an existing system modified.
- Where leachate will be recirculated to promote accelerated stabilisation.
- On areas which must be vegetated but may require further engineering works.
- Where remedial works to environmental protection systems will be needed because of settlement.

7.21 The operator should include interim and final restoration, as an overall restoration programme, in the planning application. He should give predicted timescales for the duration and completion of each stage related to

- ► site operation
- ► waste types
- ► programme for completion.

A scheme for managing areas of interim restoration, followed by the aftercare programme when full soil replacement is completed, should also be included.

7.22 On a landfill with an existing planning permission, the operator will need to agree a strategy of interim restoration with the planning authority. Interim restoration should not be used to delay final restoration unnecessarily, or lower the standard of restoration.

7.23 The water balance calculations to determine leachate production and water ingress through the capping system may take into account the effect of vegetation in reducing rainwater infiltration if so, vegetation should be established at the earliest opportunity.

Interim restoration works on site

7.24 Interim restoration requires the following site works:

- ► spreading a shallow depth of restoration material to protect the cap and support grass growth. This may comprise
  - ► up to 500mm subsoil, or
  - ► 300mm mineral or non-soil material under 300mm subsoil.

  Figure 8.2 shows a typical interim restoration soil profile
- ► open ditches to control surface water run-off
- ► stone-picking (if necessary)
- ► light cultivations, fertiliser and grass seeding.

Details of soil sampling procedures, agricultural equipment, fertiliser and seeding rates, and suitable grass seed mixes are given in Chapters 8 and 9.

- Topsoil replacement and long term final landscape features such as hedgerows and tree planting would not be carried out as part of interim restoration.
- Delayed final restoration may be unacceptable on areas which will not receive biodegradable wastes.
- There are significant advantages to early vegetation establishment on the perimeter of the site.
- On many sites substantial areas of the site will not be affected by engineering works and should be restored as soon as possible.

Advantages of interim restoration

7.25 The advantages of interim restoration are

- ► most of the subsoil and all the topsoil will remain unused and uncontaminated
- ► remedial works to environmental protection systems can proceed without costly works to
  - ► strip, save and replace topsoil
  - ► reinstate trees, shrubs and other final landscape features
- ► corrections can be made to critical gradients which may be affected by differential settlement
- ► the after-use can be developed more efficiently.

Timing of restoration

7.26 The timing of final restoration will be influenced by

- ► settlement and its effect on pollution control systems
- ► procedures for accelerated stabilisation
- ► seasonal considerations.

7.27 The operator should **co-ordinate and programme the works in advance** rather than rely upon correcting them afterwards. The restoration working plan should show restoration as a *developing process* which responds to site operations to achieve sustainable long term restoration and aftercare.

Effect of landfill gas systems on timing of restoration

7.28 Sites which accept biodegradable wastes will produce gas and be subject to settlement.

- Both the operator and the regulators should carefully consider whether it is advisable to replace the full soil depth immediately after landfilling has finished.

This sequence frequently results in the aftercare period coinciding with the period of greatest settlement and consequent disturbance to pollution control systems.

7.29 Settlement is more rapid when active gas extraction is being undertaken, and is most marked around the wells. This affects the gas control system in the following ways:

- pipework may settle and low sections may become blocked by condensate
- vertical wells may deform
- pipework connections into the wells may distort or fracture.

7.30 The gas control system is likely to need remedial works during the first 2 to 5 years after landfilling finishes. Further works may also be required to extend or modify an existing system. These works will coincide with restoration and the aftercare period. To avoid conflicts between restoration and pollution control works, ***interim restoration*** is recommended: see paragraphs 7.18 to 7.25.

7.31 This technique will help to minimise the following potential conflicts:

- planning conditions which require restoration to be completed to a pre-determined timescale, but
- site works such as drilling and laying pipework, and spreading soil and cultivations, are all done more efficiently in dry weather.

These result in restoration contractors and gas engineers working in the same area at the same time. This is likely to lead to contractual problems, additional costs, inefficiency, waste of both effort and resources, and staff frustration.

Programming restoration works

7.32 Gas control measures are essential for site safety and environmental protection, but should not override restoration and aftercare objectives. Installing the gas control system should be integrated with the restoration programme to minimise conflicts: interim restoration assists this process.

7.33 On most landfill sites soil resources are not abundant and neither subsoil nor topsoil should be wasted (see Chapter 8 for soil handling procedures). Drilling gas wells and laying pipes in areas where soil has been spread will result in damage to soil structure and contamination with other materials.

- It is neither prudent nor cost-effective to waste soil by spreading it in areas where it will be damaged or contaminated, resulting in the need to import replacement soil.

7.34 Installing gas systems into areas which have already been restored results in

- **soil compaction** caused by heavy plant such as drilling rigs and excavators

- **vegetation damage** caused by vehicle traffic or by stacking excavated materials on plants.

Piecemeal reinstatement is usually noticeably inferior to the original restoration and, even if well done, will result in vegetation establishment at different stages on the site.

7.35 The gas system should be installed **before** final restoration to avoid contaminating, damaging and wasting soil. Up to 500mm of subsoil should be spread to protect the capping layer from

- physical damage from heavy plant
- desiccation and cracking.

If material is available this may include a 300mm layer of `engineering' material (quarry overburden, mudstone or other non soil material), placed over the cap, in which the gas pipework is laid: see paragraph 7.21 and Figure 6.8. It may be necessary to delay cultivating and seeding interim restoration areas for a season, because drilling and excavation for the gas system and soils replacement should both be done during dry weather and ground conditions.

7.36 If the gas system is laid in areas to be planted with trees and shrubs final restoration and aftercare must be delayed until after the initial period of most active settlement. Interim restoration should be carried out, and the area maintained as grass until remedial works to the gas system have been completed. This may delay final restoration by up to five years, but will have the advantage of

- improving the standard of long term restoration
- reducing disturbance to newly planted trees
- making access for remedial works easier
- making restoration more cost-effective.

Traditional landfill and accelerated stabilisation

7.37 Until recently the accepted practice for landfill in the UK was full containment of the wastes, particularly for sites which had taken a high proportion of biodegradable material. Under this regime it is important to exclude water from the fill, using an impermeable capping system. This full containment philosophy remains the preferred option for the disposal of non-biodegradable contaminated wastes.

7.38 On these sites the capping layer should be covered with an adequate soil depth to prevent desiccation cracking, deterioration by weathering and physical damage. To be fully effective, soil spreading should be carried out as soon as the cap is laid.

7.39 It is most important to ensure that soil spreading, to protect the capping layer, can be carried out **when required,** *without delay.*

- All necessary soil resources should be available on site before capping commences, and a phased programme of capping and soil spreading should be agreed and followed.

7.40 Recent research on landfills which have accepted biodegradable wastes suggests that accelerated stabilisation will enable landfill to become a more sustainable and acceptable method of waste disposal. The system requires moisture to be introduced into the fill under controlled conditions, principally by leachate recirculation, to accelerate the biological processes[54].

7.41 On sites which are engineered for accelerated stabilisation an impermeable capping system is considered essential, with water (or leachate) being introduced under the capping layer at a low, controlled rate via a pipe network. These distribution pipes will be laid

- ► as soon as landfilling finishes, and therefore before settlement
- ► before the gas control system is installed or completed.

This sequence means that

- the pipes, laid to falls to evenly distribute moisture in the fill, will be affected by settlement
- the leachate recirculation system may be damaged when the gas control system is installed; and may become blocked either within the pipe or at the perforations which allow water into the waste
- these events will both reduce the efficiency of the recirculation system which may ultimately require remedial works or replacement.

Remedial works will involve lifting the capping layer to access the pipework: this will potentially disrupt large areas of restored land.

7.42 Accelerated stabilisation may also cause rapid settlement which will affect the choice of capping system or make it necessary to use a temporary capping layer.

7.43 The extent of disturbance could be reduced by installing monitoring points on the recirculation system to accurately locate the section which needs attention.

7.44 The adverse effects of accelerated stabilisation on restoration and aftercare will be minimised and controlled if the designer and operator develop a programme of restoration, including interim restoration: this programme must take account of the engineering and operational procedures.

7.45 Despite its difficulties, accelerated stabilisation offers significant advantages for restoration: the duration of settlement and landfill gas effects is likely to be much shorter than with traditional landfill practice.

[54] See WMP26B for more details of accelerated stabilisation.

Restoration strategy for old, existing sites

7.46 This advice relates to the restoration of old, existing sites which have not been restored, or closed sites where the licence is held by the operator. Separate guidance is available on remediating and reclaiming derelict and contaminated land, including closed former local authority sites which no longer have a current licence.

7.47 The problems and characteristics of existing landfills will be directly related to the previous history of the site and may include

- landform - varying from steep slopes to being too flat: may be inappropriate to the proposed after-use
- existing vegetation - may be vigorous, rank and unsightly or ecologically interesting
- shallow or contaminated cover, absence of capping layer
- inadequate soil depths or stored soil reserves, or no soil at all
- gas and leachate migration
- differential settlement
- poor quality existing restoration and aftercare
- redundant structures, derelict fencing and access points, flytipping.

7.48 The site may be covered by an old planning permission with inappropriate restoration and aftercare conditions. There may occasionally be no restoration or aftercare controls, or none that are enforceable.

7.49 The restoration strategy should follow four main steps

- desk top study
- site assessments
- design
- restoration works on site.

Desk top study

7.50 The desk top study should collate all available information on the history of the site:

- types of waste (if known)
- age of site and date of closure
- existing permissions and conditions for restoration and aftercare

- gas and leachate data, including details of the design of existing systems

- ground/surface water quality and monitoring data.

Site assessments

7.51 The initial studies should be followed by site assessments:

- *borehole investigation* - to confirm and identify the type and depth of waste

- *trial pits* - to check depth and type of cover and restoration materials

- *site survey* - existing contours, quantities of soil stored on site

- *gas migration* - monitoring migration on site through permeable site cover, and off site migration at site boundaries

- *surface and groundwater sampling* - to determine any leachate escape

- *vegetation survey* - assessment of its ecological significance.

7.52 The operator should consult the local planning authority, waste regulatory body and other statutory consultees during site assessments.

7.53 The potential of the site for landfill gas generation must be determined by reference to

- types of waste which have been placed in the site

- age of the site

- evidence of gas migration both on and off site.

On a poorly capped site, lateral migration may only become a hazard when an impermeable cap is installed or the full soil depth is spread. The potential for off-site migration must not be determined on gas venting information alone.

Design

7.54 The designer should review the existing permissions and proposed after-use. These should be revised if necessary, after consultation with the LPA and with regard to the local development plan, to more appropriately meet

- local needs and aspirations

- site characteristics (existing contours and waste types)

- soil availability

More information on design is given in Chapter 6.

7.55 The design must include

- gas and leachate monitoring and control systems
- restoration and after-use.

Landform design should suit the existing contours, if at all possible, because of the health and safety implications of excavating emplaced wastes. Importing additional material may have implications in terms of cost, severe disturbance to local roads and communities, and timing of site restoration.

7.56 The operator should liaise with the local community during the design process, especially if the site is close to houses or ecologically sensitive.

7.57 The operator must investigate sources of funding for restoration works in parallel with the design process, to develop a suitable, affordable design. Private sector or existing sites are likely to require a significant financial contribution from the operator, although grants may be available, for example for tree planting[55].

Restoration works on site

7.58 Restoration and aftercare techniques for old, existing sites are the same as those described in Part 3 of this Paper: see Chapters 8 to 12 for general soil issues and restoration and aftercare for agriculture, woodland, amenity and nature conservation and hard end uses. The following paragraphs describe only those aspects which are particularly significant on old, existing sites.

i Capping and soils

7.59 The design of the capping system must be balanced with the availability of suitable material for capping and restoration both on site and in the locality. Most old existing sites do not have enough suitable soil on site, and it is necessary to import: see Chapter 8. If clays and clayey subsoil are used for capping, this may take all readily available restoration material. In such cases an artificial capping system, such as geomembrane, bentonite mat, bentonite-enriched sand or shale, should be selected to retain available soil for restoration.

7.60 It may take a considerable length of time to accumulate sufficient soils to restore the site. Two alternative approaches should be considered.

- Restore the site in phases - suitable where rainwater infiltration will not risk ground and surface water quality.
- Establish a temporary grass cover on a shallow soil depth to protect the cap: interim restoration, paragraphs 7.18 to 7.25, with final restoration as soil becomes available.

[55] See Appendix H for information on woodland grants scheme.

ii Gas and leachate systems

7.61 The design, installation and maintenance of environmental protection systems must be integrated with restoration: see Chapters 6 and 14 and Appendix E. Interim restoration is advised on old, existing sites because it is highly likely that remedial works and modifications will be required to both gas and leachate systems in the first few years: paragraphs 7.18 to 7.25.

Restoration and aftercare contract management

Selection of contractors

7.62 The success of restoration and aftercare depends on the way in which it is carried out in the first place. The operator must therefore choose reputable contractors, experienced in the works to be undertaken.

7.63 If the CDM Regulations apply, the Planning Supervisor (see paragraph 6.8) must be reasonably satisfied that the contractor can

- competently manage and carry out the works
- comply with the safety obligations[56]
- ensure that sub-contractors comply with these Regulations.

7.64 Works may include importing subsoil and topsoil, soil spreading, drainage measures, cultivation, seeding and planting, with vegetation maintenance to follow for up to 5 years.

- If the works are let as one contract, it is iikely that some works will be subcontracted to other firms: the contract must allow approval or rejection of subcontractors.

7.65 It may be advisable to stage approval of completed works so that large contingency sums are not retained for completed earthworks throughout a protracted vegetation maintenance period.

7.66 Alternatively planting and vegetation establishment and maintenance could be let as a separate contract. This will allow a contract Completion Certificate to be issued, and contingency sums retained throughout the maintenance period released upon satisfactory completion of the works.

Forms of contract

7.67 The choice of the most suitable form of contract will depend upon the information available when tender documents are prepared, and the degree of risk either party to the contract wishes to take.

[56] Management of Health and Safety at Work Regulations 1992, Approved Code of Practice, HSE; CDM Regulations 1994, Managing Construction for Health and Safety, Approved Code of Practice, HSE, 1995.

7.68 The Institution of Civil Engineers (ICE) Conditions of Contract (6th edition) is a good format if the works can be specified in detail. It has the advantages of

- ease of remeasuring works
- high degree of control on the part of the employer.

It also tends to be rigid, time-consuming to administer and cumbersome for landscape works.

7.69 The ICE Minor Works Contract is more flexible and simpler to administer, making it more suitable for smaller jobs with a contract sum of less than £100,000. It relies more heavily upon the contractor's experience and requires a less detailed specification, making it more suitable in situations where it is not possible to specify and quantify the works in detail in advance.

7.70 The New Engineering Contract (NEC) allows a better team approach, and is most helpful if a complicated site requires a step by step approach. It allows a range of options, such as lump sum, cost reimbursable and management contract[57].

Specification of the works

7.71 Careful and thorough specification of the works is essential. The contract should specify the sequence of works to be undertaken in a clear and logical order, giving detailed information on

- type of equipment to be used
- weather and ground conditions under which works will not be permitted
- techniques to be used.

Reference to the relevant British Standards is also useful.

7.72 The specification should include

- *Soil acquisition* - quality and characteristics of the soil to be brought to site (clay content, stoniness, absence of perennial weeds, moisture content); whether the source of the soil must be approved before the contract is let.
- *Soil handling* - type of plant to be used, ground and weather conditions, depths of stripping and replacement.
- *Cultivations* - type of equipment to be used, depth of cultivations, soil sampling and analysis, size of stone to be removed, fertiliser applications, standard of seedbed preparation, seed mixtures, seeding rate.
- *Fencing and drainage* - style of fencing to be erected, materials to be used; depth of drainage pipes, materials to be used, type of backfill, profile of open ditches, outfalls.

[57] More information on forms of contract is given in WMP 26B, Chapter 4.

- *Planting* - size, age and species of plants to be used, time of planting, pre-planting operations, method of planting, pest control measures.
- *Maintenance* - fertiliser applications, frequency and height of grass cutting, weed control methods, replacement of dead or damaged plants, reinstatement of unsatisfactory areas, initial thinning, pest and disease control.

Quality assurance and contract supervision

7.73 The contract must be supervised by experienced personnel with the authority to control the contractor on site.

- This is important if aftercare works are being carried out by a sub-contractor, controlled by the earthworks main contractor: delays in issuing a site instruction may adversely affect the standard of work.

7.74 On smaller sites where the civil engineering input is less than the landscape input, a landscape consultant should be employed to prepare and manage the restoration and aftercare contract. This may also apply to landscaping works which precede site development and operation.

7.75 Restoration and aftercare works should be measured using a suitable Standard Method of Measurement (e.g. CESMM, SMM7), which allows flexibility for admeasurement of quantities because the exact extent of the work cannot always be ascertained at tender stage. Maintenance works to grassland, water features, planting and fencing works should be measured separately: a performance element may be introduced into the method of measurement.

7.76 The principal contractor should retain a competent and experienced Agent on site at all times to plan, manage and supervise the works, control any subcontractors and to liaise with the employer or his superintending officer.

7.77 Before tenders are sought the Planning Supervisor (if CDM Regulations apply) will have prepared a Health and Safety Plan[58] for issue with the tender documents. It need not form part of the contract. This is a vital document which advises potential contractors of

- site conditions
- inherent risks involved in the works
- other relevant site specific information.

[58] See Appendix F for further information on the CDM Regulations Health and Safety Plan.

The plan will contain information under the following headings

- Nature of the project
- Existing environment
- Existing drawings
- The design
- Construction materials
- Site-wide elements
- Overlap with operator's other site activities
- Site rules
- Continuing liaison.

7.78 The principal contractor, when appointed, will become responsible for health and safety matters, and for developing the Health and Safety Plan as the works proceed. The Planning Supervisor is responsible for preparing a Health and Safety File. This file will contain

- ► record drawings and `as built' plans produced during construction, with the relevant design criteria
- ► general details of construction methods and materials
- ► details of installed equipment and maintenance facilities
- ► maintenance procedures and requirements, operator's manuals for specialist items
- ► details of the nature and location of existing or installed services, and restrictions on site use or operations which they impose.

7.79 The principal contractor may play a major part in preparing and updating the Health and Safety File. After completion of the contract the Planning Supervisor will review and finalise the File and then hand it over to the operator for future use. It would form part of the site manual.

Chapter 8

Soil in restoration and aftercare

Introduction

8 This chapter deals with soils and their uses in restoration (soil replacement) and during aftercare (cultivation and fertiliser applications). It is intended to be helpful to practitioners and contractors.

8.2 The chapter describes

- soil survey and assessment techniques: paragraphs 8.9 to 8.15
- soil requirements for restoration: paragraphs 8.16 to 8.40
- techniques for soil handling to minimise damage: paragraphs 8.41 to 8.91
- cultivation methods: paragraphs 8.92 to 8.96
- soil amendments: paragraph 8.97.

Further information on soil properties is contained in Appendix A.

8.3 Soil is the basic material for all restoration to soft after-uses. Restoration success depends on

- identifying all soil available on site or likely to become available by importation
- conserving and making best use of these resources
- handling soils during stripping, storage and respreading to minimise damage
- carefully planning and supervising all soil handling operations.

8.4 The operator should provide detailed information and proposals on soil resources, restoration specifications, soil movement and storage, and soil handling methods at the planning application stage. This will help to ensure that sensible restoration conditions can be agreed.

8.5 Soil quantities for stripping, storage and replacement should be included in *materials balance calculations*[59]. These are particularly important on sites with phased development and restoration.

[59] See WMP 26B for detail on materials balance calculations.

Soil survey and assessment

8.9 The best soils for restoration are the natural soils which previously existed on the site. The operator should carry out a survey of all on-site soils early in the design and assessment process.

- The landfill design and restoration working plan must take account of the need to strip, carefully store and re-use all on-site soil.

8.10 Published soil maps are rarely sufficiently detailed to assess soil resources accurately. A detailed, site specific, soil survey should be carried out using at least one hand auger observation point per hectare (often on a 100 x 100 m grid)[60]. The objectives of the soil survey are

- ► to provide practical guidance on the soils available for restoration
- ► to describe the types of topsoils and subsoils (which may have to be handled separately), their distribution, thicknesses and volumes.

This information should be used to prepare a soil survey map and a soil resource schedule: see Figure 8.1 and Table 8.1.

8.11 In assessing the types of soil available on site the following key soil properties must be noted:

- *Texture* - affected by relative proportions of sand, silt and clay; determined reasonably accurately by finger assessment (the 'feel' of a moist soil sample); sand imparts grittiness, silt a smoothness, clay a stickiness while loams feel doughy.
- *Structure* - created by soil particles aggregating together, affected by texture, wetting and drying and organic matter; clayey soils are potentially well structured unless waterlogged, sandy and silty soils usually have weakly developed structure easy damaged by cultivations or mechanised handling; topsoils are usually well structured.
- *Colour* - varies with moisture content. Dry soils are paler than the same soil when wet; grey or mottled soils indicate periodic waterlogging and poor drainage; a darker colour indicates organic matter.
- *Organic matter* - influences soil fertility as it breaks down, releasing plant nutrients and producing humus; chiefly found at the soil surface resulting in organic matter in the top 200 - 300mm making topsoil more fertile than subsoil.

[60] See Appendix A.

Figure 8.1 Soil survey map

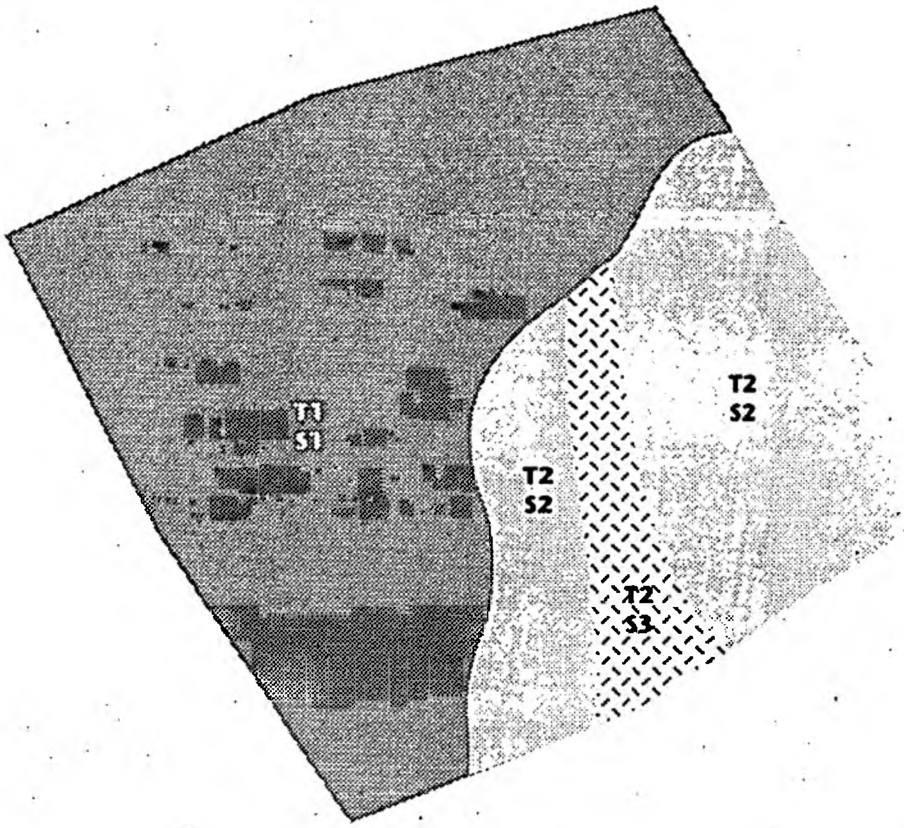
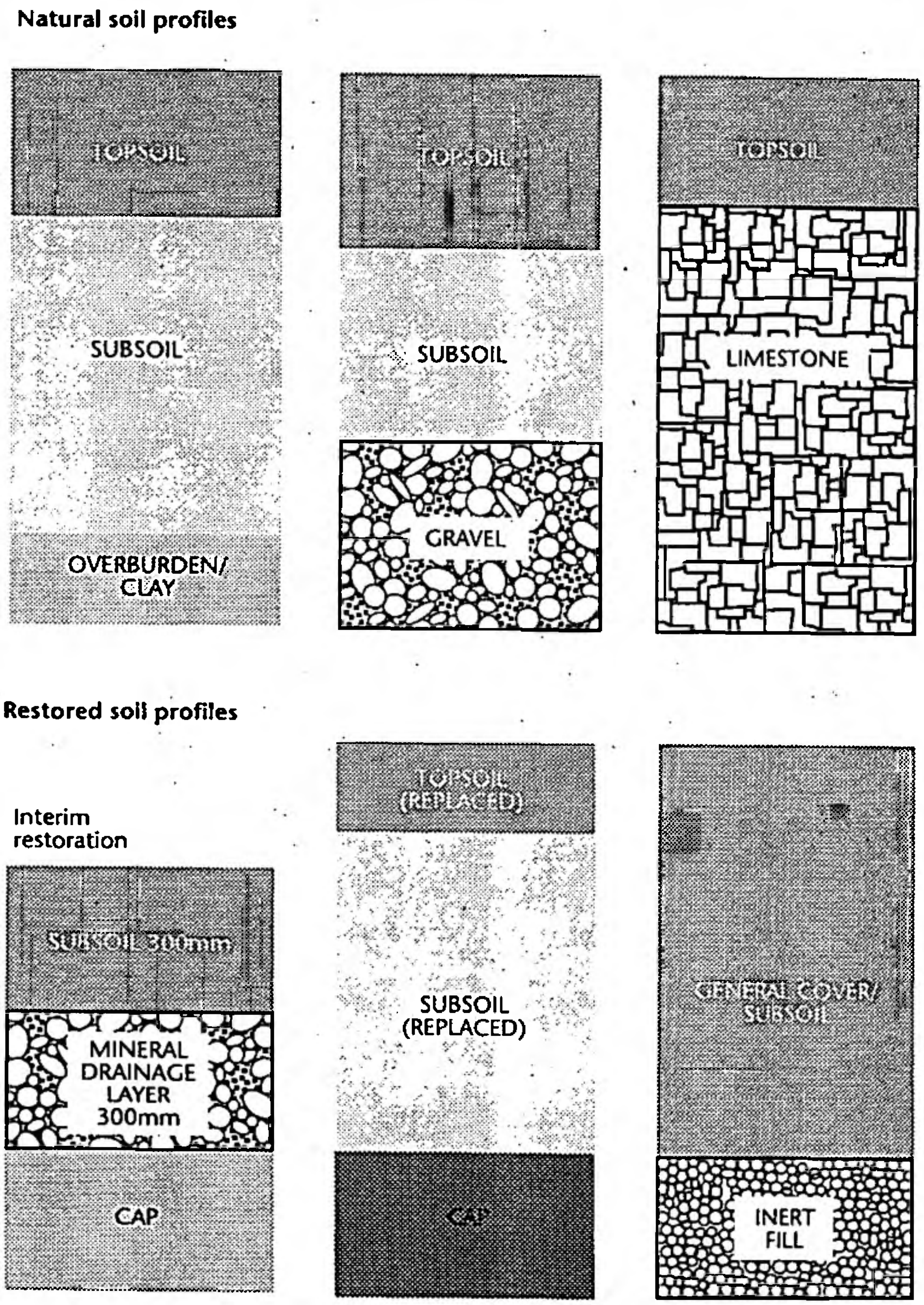


Table 8.1 Soil resource schedule (survey results of figure 8.1)

Unit	Description	Depth mm	Area ha	Volume m^3
T1	Sandy loam topsoil	300	7	21,000
T2	Clay loam topsoil	200	2.5	5,000
S1	Sandy clay loam subsoil	700	7	49,000
S2	Clay loam subsoil	550	2.5	13,750
S3	Clay subsoil	300	1	3,000

Figure 8.2 Typical soil profiles



8.12 The soil survey will identify the characteristics of the ***soil profile*** and the depths of each **horizon** (layer) in the profile: see Figure 8.2. For most practical purposes three horizons should be distinguished - topsoil, subsoil, and overburden or parent material.

- Topsoil. The darker, organic rich surface horizon, usually cultivated and normally 200 to 300mm thick (see also definitions used in British Standard BS 3882 in Appendix A).

- Subsoil. The underlying soil, usually paler in colour, but with a recognisable structure, and into which the deeper plant roots extend for moisture and nutrients; normally extending to about 1 to 1.2 m below the surface.

- Overburden. Soil parent material, the geological material from which the soil has formed, may be difficult to distinguish from the subsoil, but will lack roots and a soil structure.

Not all soil profiles have all three horizons and the thicknesses of each may differ from the figures quoted above. The subsoil depth may vary: it may be very shallow over parent rock or sticky clay, or more than 2 m deep. Some soil profiles may have more than one subsoil layer, and terms such as `upper subsoil' and `lower subsoil' may be used in profile description. The soil survey should identify all the useful soil resources available on site.

8.13 Geologists and other specialists may use different terminology to describe soil profiles to that explained above. For example, the term ***soil*** may be used to describe both topsoil and subsoil, or the term ***overburden*** may include subsoil. These terms are inadequate for evaluating and describing restoration materials.

8.14 During the soil survey samples should be taken for analysis.

- Soils are usually tested for pH, lime requirement and fertility (levels of plant nutrients - phosphate and potash).

The laboratory analysis will also confirm the finger assessment of soil texture. Non-soil or derelict land materials should be tested for heavy metals, principally zinc, copper and nickel, if it is suspected that the site may be contaminated: see paragraphs 8.30 and 8.32.

8.15 Representative samples of topsoil and subsoil must be taken from all parts of the site to give a reliable assessment. In addition to these general samples, any unusual material within the soil profile should also be sampled. A reputable laboratory should be used, and some laboratories will also carry out the soil sampling on site. Soil testing for toxic substances is a specialised procedure and expert advice should be sought[61].

Soil requirements

8.16 Consideration of soil requirements for restoration includes

- ► thickness of restoration materials: paragraphs 8.17 to 8.18
- ► choice of restoration material: paragraphs 8.19 to 8.24

[61] Details of soil sampling procedures is given in Appendix A.

- imported soils: paragraphs 8.25 to 8.29
- soils from unknown sources: paragraphs 8.30 to 8.35
- soil substitutes: paragraphs 8.36 to 8.40.

Thicknesses of restoration materials

8.17 The restoration profile, and the depths of different soil types, depend on the after-use: Table 8.2 gives the recommended minimum depths of restoration material (soil and overburden) over different types of landfill, related to the after-use. The topsoil and subsoil requirements for each after-use are described in the following chapters: Chapter 9, agriculture; Chapter 10, woodland: Chapter 11, amenity and nature conservation.

8.18 The depth of restoration material will depend on the type of landfill and the proposed after-use. Vegetation will establish on 500mm of soil but a greater thickness is needed

- to protect an impermeable cap
- to accommodate gas control systems and land drainage systems
- for plants with an extensive root system.

Choice of restoration material

8.19 The recommended minimum depths in Table 8.2 may include overburden or mineral non soil material. Vegetation establishment will be easier if topsoil and subsoil are used. Because it is difficult to guarantee the minimum depth over the whole site, the operator should aim to provide up to 20% more than the minimum depth to give a margin for variations in grade.

8.20 For agriculture the soil profile must include topsoil and subsoil; woodland and nature conservation after-uses will establish without topsoil. In agricultural land, gas extraction pipes should be laid in a 300 mm layer of mineral non-soil material (see Figure 6.8 and paragraphs 7.22 and 7.35); this layer should be in addition to the 1 m soil depth. The interim restoration profile would include this non soil layer plus approximately 300 mm of subsoil: see Figure 8.2.

8.21 Topsoil is necessary where the after-use needs high fertility and vigorous plant growth, for example agriculture: a depth of 250 to 300mm should be used. Plant nutrition problems should be corrected using lime and fertiliser. Trees do not need topsoil, and for some low intensity uses such as amenity or nature conservation, a better result will be achieved if topsoil is not used at all: see Chapters 10 and 11.

Table 8.2 Recommended minimum soil depth over various types of landfills

Type of landfill	After-use	Minimum thickness of soil and other cover (m)
Non-inert, capped with clay and with piped gas control system	Trees	1.5
	Arable agriculture, requiring underdrainage	1.0
	Grazing or amenity, no large trees, no underdrainage	1.0
	Other afteruses e.g. car-parking, hard-standing	1.0
Non-inert, capped with synthetic materials	Trees	1.0
	Arable agriculture, requiring underdrainage	1.0
	Grazing or amenity, no large trees, no underdrainage	1.0
	Other afteruses e.g. car-parking, hard-standing	1.0
Inert or similar with, no capping layer or gas control system	Trees	1.0
	Arable agriculture, requiring underdrainage	1.0
	Grazing or amenity, no underdrainage	0.5
	Other after-uses e.g. car parking, hard-standing	0.5

8.22 The calculated soil requirements should be compared with the available on-site soil. This materials balance calculation will be used in developing the restoration strategy. The operator should review the choice of after-use in the light of the soil survey information, investigating after-uses which require less soil if soil availability is limited: see Chapter 4.

- The operator and the planner should use soil survey information to develop a realistic restoration specification.

8.23 If there is insufficient soil to meet a restoration specification, the operator and planners should consider

- reviewing the restoration specification on all or parts of the site, but only where any new specification (reduced soil thicknesses or changed soil type) does not compromise the success of the after-use
- using overburden or weathered materials beneath the subsoil to increase the restored profile depth
- importing soils
- evaluating potential soil substitutes.

8.24 The operator must make every effort to

- ensure that all original *in situ* soils, potentially useful overburden, weathered sub strata or other soil substitutes are conserved for restoration
- prevent stored soils being taken for inappropriate uses during operations, e.g. for intermediate or daily cover within the landfill
- make arrangements to import soils, if necessary, as early as possible to take advantage of sources of good material as they become available.

Imported soils

8.25 If soil must be imported for restoration, the operator must consider the following.

- The amounts of topsoil, subsoil and overburden which are readily available in the area compared with the total amount required.
- How consistent the material is; a single soil type will give more consistent restoration results.
- Whether the soils are free of toxic materials; some imported soil is of suspect provenance, and may contain substances harmful to plants and animals.

8.26 Before accepting soil on site for restoration the source site should be inspected and approved. Close supervision by experienced site staff is necessary to ensure that the specification is maintained and that inferior soils from another source are not substituted.

- Unacceptable or questionable material should either be rejected or at least set to one side and tested before use.

The best source of imported soils is a greenfield development site: if possible the soils available on the source site should be surveyed and assessed as for *in situ* soils.

8.27 The characteristics of an ideal imported material are

- a loamy texture (not too sandy or clayey) and good structure
- relatively stone free
- chemically fertile, with a pH of about 6.5.

Topsoil should meet the BS 3882 specification for general purpose or economy grade topsoil. If the imported soil is similar to the *in situ* or local soil, the same types of crops and other vegetation will grow, which will help to integrate the site into its surroundings.

8.28 The *British Standard BS 3882 Specification for Topsoil*, published in 1994[62], recognises three grades of topsoil - premium, general purpose and economy. The BS does not cover subsoil. The 3 grades are defined as follows.

- *Premium grade* - natural topsoil, having high intrinsic fertility, loamy texture and good structure.
- *General purpose grade* - includes natural topsoil, premium grade topsoil that has deteriorated due to poor handling, or a manufactured soil which has appropriate qualities.
- *Economy grade* - derived from i) topsoil of lower quality than general purpose topsoil or ii) material such as selected subsoil or friable mineral matter suitable for plant growth.

8.29 General purpose topsoil is suitable for good quality agriculture, recreation and commercial woodland. Economy grade material is suitable for amenity woodland, less intensively used amenity grassland and agricultural land of low productivity.

Soils from unknown sources

8.30 If soils from an unknown source are to be used for restoration the operator should assess the material against the following criteria:

- *appearance* - is the material generally "soil-like"? Does it have a structure, or is it a slurry or occur in massive blocks?
- *colour* - is it soil-like in colour, that is, basically black, brown or grey? Soil need not be rejected if the colour is derived from the underlying geology, but unnatural colours may indicate chemical contamination and should be avoided.
- *uniformity* - is the colour and texture uniform? Soil which appears to be a mixture of materials should be analysed; mottling in shades of greys and browns generally indicates a poorly drained source and is best avoided.
- *moisture content* - very wet materials should be avoided.

[62] See Appendix A.

- *physical contamination* - does the soil contain foreign materials such as brick, concrete, asphalt, glass, timber, plastic and pieces of metal? These adversely affect the quality of the soil, and the material should be screened before use.

- *chemical contamination* - is the soil visibly contaminated with tarry or oily substances? Such soils should be avoided.

- *organic content* - are there signs of organic debris? The presence of roots, leaves, turf or similar natural organic matter is a sign that the material is likely to be topsoil (but note BS 3882 restrictions regarding weed content).

8.31 If the operator suspects that imported material does not meet the required specification he should either reject it or have it tested before use. The most useful tests are those used to characterise the grades of topsoil in BS 3882, especially plant nutrients (phosphate, potash, magnesium) and pH. If these are within acceptable values, the soil is probably safe to use.

8.32 It may also be wise to analyse the heavy metal content. This may be done either by laboratory analysis or by growing test plants[63]. Soil analysis results should be compared with the concentrations recommended by the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL) to denote `clean' uncontaminated material and potentially toxic levels[64]. Advice should be sought from specialist laboratories or consultants.

8.33 Importing soil to site, especially from unknown sources, may inadvertently bring contaminated materials to site. The operator must be aware that the Duty of Care principle applies to the acceptance of such materials. To ensure that contaminated materials are not imported for use in restoration, soils should be investigated **at source**. Testing individual loads is time-consuming, inconvenient and expensive.

8.34 The physical properties of imported soils can be improved by removing large stones and other debris which may hinder cultivations. Attention should be concentrated on the topsoil and upper subsoil: large stones below 500mm depth do not normally pose significant problems except when installing underdrainage. Stones can be removed by

- ► screening the material before spreading

- ► ripping and cultivating the placed material and stone picking manually or by machine.

Screening soils may damage their structure and remove organic matter; screened material should always be carefully assessed and handled.

8.35 Fertilisers and organic manures should be added to infertile material. Lime should be added to raise the pH to acceptable levels. The effects of high heavy metal concentrations can be temporarily controlled by maintaining a soil pH above 7 but these soils should not be used for restoration.

[63] A suitable method is given in BS 7755 Soil Quality.

[64] ICRCL Guidance Note 59/78 Notes on the Assessment and Redevelopment of Contaminated Land.

Soil substitutes

8.36 Many imported materials are variable and possibly contaminated, and their quality is poor. The operator may therefore prefer to use soil substitutes, particularly if large quantities of uniform material are available.

- Where true soils are not available, the use of on-site soil substitutes will significantly reduce the amount of soil to be imported: this is important where soils are scarce or where access to the site is unsuitable for heavy goods vehicles.

Substitute soils are usually suitable only as subsoil or where infertile soil is acceptable, such as amenity woodland and nature conservation after-uses.

8.37 Possible sources of soil substitutes include

- *overburden* - material lying below the soil; ideally this should have a low content of large stones and be neither very clayey nor very sandy; it may have low pH, will have no organic matter and no nitrate but can have variable amounts of other nutrients
- *colliery spoil* - this has serious physical and chemical limitations, particularly very low pH in many areas of the country, low nitrate and phosphate levels, poor structure, poor drainage, poor available water capacity, and development of high surface temperatures
- *other mining spoil* - the same considerations apply as for overburden
- *waste chalk or limestone* (except arising from chemical/industrial processes) - this has high calcium carbonate content, high pH and low nutrient levels; with fertilisers, vegetation establishment and growth can be good; high stone content (flints or hard limestone fragments) can be a problem
- *waste sands* (except foundry sand) - these will provide good drainage, but low or very low available water capacity, very low nutrient content and probably very acid pH; added lime and fertiliser are rapidly washed out
- *sediment* (from silt ponds or tailings lagoons) - initially this will be a slurry and should be allowed to dry out and "ripen"; material from tailings lagoons should be checked for levels of phytotoxic elements
- *dredgings* - as for sediment above, possibly with added complication of salinity and heavy metal contamination; may be otherwise quite fertile
- *pulverised fuel ash (pfa)* - most useful in combination with other materials, since its high content of silt/fine sand can improve clay materials; relatively infertile and requires fertiliser and organic matter; some pfa has harmful levels of boron
- *composted green waste* - this may be a useful addition to or substitute for topsoil; composted whole waste is not suitable as a soil substitute.

8.38 Expert assessment is necessary to check the suitability of these materials in restoration. Field trials may be required to assess their potential for plant growth, with or without ameliorants.

8.39 Most soil substitutes will be infertile: fertilisers, lime or sewage sludge may be needed. Alternatively an after-use such as nature conservation should be chosen, using plant species which are tolerant of the low fertility. This will be more cost-effective than trying to maintain vegetation which needs substantial and on-going fertiliser applications: see Chapter 11.

8.40 The operator should be aware of the possibility of surface water and ground water contamination caused by run-off from soil substitutes, and take suitable preventative measures.

Soil handling

8.41 This section describes issues which relate to soil handling, by reference to the following.

- Soil movement plan: paragraphs 8.42 to 8.44
- Timing of soil movement works: paragraphs 8.45 to 8.56
- Supervision of earthmoving operations: paragraphs 8.57 to 8.58
- Soil handling equipment and their effect on soil: paragraphs 8.59 to 8.70
- Soil stripping: paragraphs 8.71 to 8.73
- Soil storage: paragraphs 8.74 to 8.80
- Soil replacement: paragraphs 8.81to 8.82
- Alleviation of soil compaction by subsoil ripping: paragraphs 8.83 to 8.89
- Stone picking: paragraphs 8.90 to 8.91.

Soil movement plan

8.42 A detailed scheme of integrated working and restoration, included in the restoration working plan, will include a schedule of soil requirements and available soil resources: see Table 8.1. The operator should make arrangements for dealing with soils and other suitable materials which become available whilst the site is operational.

8.43 Wherever possible soils should be moved directly from the phase being stripped to the phase being restored, thus avoiding intermediate storage. This method of working will

- ► minimise soil handling and thus reduce damage
- ► reduce soil storage thereby reducing the risk of soil loss and the need for designated storage areas
- ► reduce handling costs.

8.44 Predicting and co-ordinating soil stripping and restoration on different parts of the site can be logistically very difficult. The soil movement plan must be related to site phasing and take account, as far as possible, of the distribution of different soil types on site. Sites which have a complex mixture of soils should be restored into more uniform blocks of single soil types which are easier to farm.

Timing of works - soil and weather conditions

8.45 Soils should be handled under dry conditions to avoid compaction. These conditions may be difficult to achieve on sites in high rainfall areas and with poorly drained, heavy textured soils.

8.46 Criteria for determining dry conditions may be based on

- i bad weather and waterlogging
- ii seasonal considerations
- iii plastic limit criteria and measurement of soil moisture content.

8.47 For both soil stripping and replacement, criteria based on weather conditions, waterlogging and soil plastic limit are recommended. For soil replacement only, seasonal criteria. The operator should balance the need to carry out soil handling operations and the need to safeguard soils.

i Bad weather and waterlogging

8.48 Soil stripping and replacement should cease when the ground or the soil itself is

- wet or waterlogged, with pools of standing water
- frozen or covered by snow.

Criteria based on rainfall, which state that soil handling should be delayed after rainfall for a waiting period (depending upon the amount of rain), take no account of how wet the soil is to start with or how quickly the soil dries out. They are no longer recommended.

ii Seasonal considerations

8.49 As a general principle, soil stripping and respreading should not take place in winter. At this time

- soil moisture content is relatively high
- soils are highly susceptible to damage by compaction, smearing and rutting.

Even if the topsoil appears dry, subsoil is likely to be too moist to move. In addition the likelihood of rain and cold weather makes it unwise to start such works during this season.

8.50 When reinstating soil, every effort should be made to complete work in early autumn, giving time to establish a crop cover before the onset of wet weather. At this time falling temperatures and declining crop growth mean that, once soils become wet, they then normally remain wet until the following spring. Topsoil replacement should be finished early enough to complete cultivations and crop establishment during dry weather.

8.51 The actual period available for soil handling operations varies from year to year. Estimates can be made for planning soil placement based on location and climate:

- in wetter areas it is best restricted to the summer months (June to August inclusive).
- in the drier areas of eastern England, it is often possible to achieve satisfactory results from May to mid October.

Furthermore, these periods may be lengthened by up to a fortnight where sandy soils occur; and should be reduced by this amount where heavier textured materials, such as clays, are encountered.

iii Plastic limit criteria

8.52 Relatively dry soils which are loose or friable will be in a suitable condition for soil stripping by all machinery. Wetter, plastic soils are unsuitable for mechanised soil handling. The point at which a friable or loose soil changes to plastic is called the *Lower Plastic Limit*, or simply the plastic limit.

8.53 The assessment of whether or not a soil is plastic can be open to argument and some planning authorities have demanded that the moisture content of the site soil at its plastic limit should be pre-determined by a competent laboratory. This can create practical difficulties during the earthworks contract, and a simple field test giving a reasonably accurate assessment of soil plasticity is more appropriate:

- the plastic limit in a soil is reached at the point at which a pre-moulded ball of soil just fails to be capable of being rolled into a 3mm diameter thread on a glass surface.

8.54 The key criterion for mechanised soil handling is that

- **the soil is not plastic or wet.**

Neither medium textured soils in moderate and high rainfall areas, nor clay soils dry out to their full depth for any significant period, if at all. In such circumstances, to ensure that a reasonable balance is struck between the need to work sites and the need to minimise soil damage, a compromise needs to be made.

8.55 One option is to apply the plastic limit test to the upper 600mm only. To cater for extreme years and very wet areas, further modification may be applied so as to permit stripping between June and August (inclusive) where the upper 300mm is non-plastic.

8.56 Where the landfill follows mineral working in `best and most versatile' land, such compromises may not be acceptable. However soil handling may be permissible if a method is used which does not impose pressure on the soil e.g. the dump truck and back-acter method, operated so that the machinery does not traffic over the soils.

Supervision of earth-moving operations

8.57 All operations involving soils or other restoration materials must be carefully supervised. During both ***soil stripping*** and ***soil replacement*** the operator must ensure that

- skilled staff are employed
- staff are fully instructed, with access to relevant planning and restoration documentation
- staff have the authority to modify or stop operations which will affect the success of restoration.

8.58 Supervisory staff should ensure that the points in Table 8.3 are observed. A *lightness of touch* is essential in soil handling. This contrasts with the instructions which the operator will give a machine operator placing landfill or the capping layer.

Table 8.3 Supervision of soil handling works

Operation	Key consideration
Soil stripping	All available topsoil, subsoil and other soil resource materials (overburden) are separately stripped.
	Materials from different soil types are separately stripped.
	Soils are only stripped in suitable conditions.
	Soil handling machinery'is operated so as to minimise compaction.
Soil storage	Soils, including imported soils or soil substitutes, are stored in pre-determined and prepared locations.
	Storage heaps are constructed to the correct dimensions and are grassed down after construction.
Soil placement	Soil types are replaced in correct sequence and to the specified depths.
	Soils are only replaced in suitable conditions.
	Soil handling machinery is operated to minimise compaction.
	Any soil compaction is alleviated by ripping.
	Control measures are in place to deal with run-off and erosion.

Soil handling equipment and its effect on soils

8.59 The main damage to soils during mechanised handling is loss of soil structure and compaction caused by traffic, particularly wheeled traffic, over the soils. Recently replaced soils are especially vulnerable to compaction, which can be relieved by subsoiling or ripping.

8.60 Table 8.4 summarises the effects of disturbance on the different soil characteristics, and how those effects may be controlled and minimised.

8.61 In compacted soils the soil pores and fissures which contain air and water are disturbed, so that they impede drainage and cause waterlogged conditions. Compaction discourages plant root penetration, so that they remain near the surface and can be affected by droughtiness during the summer.

- Compacted soils are too wet in the winter, too dry in the summer.

8.62 Rainwater infiltration is severely limited in compacted soils leading to a greater risk of run-off on sloping land. Cut-off ditches should be designed to cope with run-off, especially following heavy rain. These are very important until the vegetation establishes. Rapid run-off may cause soil erosion with the eroded soil being washed into watercourses. Suitable control measures, such as retention ponds, must be use to prevent silt-laden drainage water from leaving the site: see Chapter 9.

8.63 The operator can avoid an unacceptable amount of soil compaction by

- ► using low ground-pressure equipment - tracked tractors, bulldozers and articulated dump trucks, rather than motorscrapers and large dump trucks
- ► minimising traffic over the soils, by the correct choice of soil handling equipment and method of operation[65]
- ► handling soils when dry: see paragraphs 8.48 to 8.56.

[65] See Appendix A for more detail on soil movement.

Table 8.4 Soil characteristics and effects of disturbance

Soil characteristics	Effects of disturbance	Effects controllable by planning conditions
Soil profile and depth: arrangement and thickness of different horizons (topsoil, subsoil and weathered parent material)	Possible mixing of different soil horizons, loss of material, possible bulking during soil movement and subsequent resettlement	Careful separation, stripping, storage and respreading of soil horizons commensurate with amounts of soil actually present
Soil texture: size range of primary particles present (sand, silt, clay, etc)	Not necessarily altered if soil movement carefully controlled	Careful separation, stripping, storage and respreading of soil layers
Soil structure: arrangement of individual soil particles into larger, compound units or peds with channels between	Inevitable disturbance by soil movement; extent depending on type of structure and conditions of movement. Compaction; increase in bulk density; impeded drainage	Method of soil movement; avoidance of movement in wet conditions; direct respreading where possible, subsoiling and other cultivations on replaced soil; remedial cropping
Bulk density: the weight of soil per unit volume. A measure of compaction	Possible loosening during stripping decreases bulk density but main danger is increased bulk density by passage of earthmoving machinery over it	As soil structure
Soil drainage: movement of water through the soil. Depends mainly on soil texture and structure; and level of water Table	Disturbed by soil movement	See soil texture and structure. Levels and gradients of reinstated sites; subsequent installation of drainage system
Available water capacity: measure of moisture which plants can extract from the soil. Related to soil texture and structure	May be altered by soil movement	Not directly
Nutrient status and chemical characteristics: content of main plant nutrients (nitrogen, phosphorus, potassium, calcium, magnesium), acidity (pH), and micronutrients (such as manganese, copper, molybdenum, iron).	Soluble compounds leached during storage of soils, and pH may be lowered. Anaerobism in wet/compacted soils	Addition of lime and fertilisers, as indicated by ADAS analysis, on replacement of soils and during aftercare period. Occasionally may need fertiliser and lime added to soil stockpiles.

i) Motorscrapers

8.64 Motorscrapers inevitably cause some degree of soil compaction since

- the rear wheels of the scraper pass over the soil which has just been laid, and the front wheels and/or tracks compact material previously laid and hide the compaction under newly laid soil.

Compaction will be minimised by

- using designated haul routes and not allowing machinery to run randomly over the site - especially over replaced soil
- maintaining a steady forward movement, without wheel or track slippage
- running over the `lowest' material available (i.e. overburden rather than subsoil, subsoil rather than topsoil) so that the scraper travels on the lowest possible material, only turning onto the material to be stripped at the point of soil pick up and turning off it again as soon as possible.

8.65 Compaction cause by motorscrapers must be alleviated by **subsoil ripping:** see paragraphs 8.83 - 8.89). Repeated subsoiling may be necessary. However, compact layers may still remain at depth, where they cannot easily be loosened: this may have serious consequences on soil drainage during aftercare. The operator should avoid trafficking over all soil layers to minimise compaction.

ii Dump trucks and back-acters

8.66 Compaction can be avoided using the *loose tipping* technique whereby the soils are stripped and replaced by a back-acting or 360° excavator and transported by dump trucks. The trucks should run on the compacted clay cap or other non-soil cover. The soil must be stripped and replaced in strips. Soil handling costs can be up to 50% higher, but subsequent subsoiling should not be needed. The respread soils should be graded using a low ground-pressure tracked bulldozer.

8.67 To be successful, dump trucks must avoid the spread soils entirely. This may cause practical difficulties:

- it may be necessary for trucks to run over soil to access certain areas, or for manoeuvring
- certain capping materials must be protected with soil before earthmoving machinery can run over it, resulting in machinery having to run over the lowest layer of soil.

Dump trucks will cause as much compaction as motorscrapers: subsoil ripping will therefore be necessary if trucks have run on spread soils, especially on haul routes.

8.68 Loose tipped soil is much more permeable and so run off and erosion should be greatly reduced. However, soils tend to settle after placement and until they do, low ground-pressure agricultural machinery may be required for aftercare works.

iii Bulldozers

8.69 These use a blade to spread and grade soil. The tracks of the machine pass over the spread soil, but the ground-pressure is sufficiently low for this not to cause significant damage.

iv Other traffic

8.70 When soils have been placed, the minimum amount of surface levelling should be carried out, using light agricultural machinery. The operator must avoid repeated movement across recently reinstated soils by earthscrapers or bulldozers to produce an even grade for aesthetic reasons. Traffic which is not directly involved in soil placement should not be permitted to run over subsoil or topsoil.

Soil stripping

8.71 Soil stripping operations must be planned in advance. A large enough area must be stripped from each operational phase for site development, operations and access. Site operators must be given very clear instructions with regard to

- stripping all available soil resources without cross contamination of one material with another
- depths of soil to be stripped from each area
- which soil resources must be stripped and stored separately
- what machinery he will be permitted to use
- the sequence of stripping and the planned haul routes
- under what weather and ground conditions he will be prohibited from working.

8.72 Topsoil and subsoil must be stripped and stored separately. If different soil types exist on site which must be kept separate the operator should make arrangements to strip, store and replace them separately.

8.73 If a soil profile similar to that which existed previously is to be reinstated the different horizons - topsoil, subsoil and overburden (if any), should be stripped and reinstated in the correct sequence. Saving and replacing only the topsoil is not acceptable practice. The operator must not allow subsoil to become mixed with overburden or topsoil.

Soil storage

8.74 On sites with in situ soils, the restoration design and strategy should take the soil stripping and replacement programme into account. Ideally soils should be stripped and directly moved to the area being reinstated. Where this is not possible, soils must be stored. The operator should ensure that

- sufficient area is available to accommodate the volumes of soil to be stored, assessed by the soil survey: see paragraphs 8.9 to 8.15

- different soils can be stored separately

- soil stores can be accessed in the correct sequence.

8.75 If the site has already been stripped, the amounts and nature of the material in storage mounds should be assessed.

8.76 The operator should make provision for storing imported soils since these are unlikely to become available when they are required. This is particularly relevant on sites where soils are accumulated during operations from small loads of suitable materials arriving on site: see paragraphs 8.25 to 8.35.

8.77 All soil, but particularly topsoil, alters during storage because the bulk of the heap becomes anaerobic. Most of the changes quickly reverse when the soil is dug out and re-spread although the populations of micro-organisms and structural stability may take longer to recover.

8.78 To minimise the changes, soil storage heaps should be built as loose as possible. Restrictions on the dimensions of the heaps and length of time soil should be kept in storage may not be helpful, leading to storage heaps being limited to unrealistically small dimensions.

- Restricting topsoil heaps to less than 3m in height does not prevent the soil from rapidly becoming anaerobic.

On some larger phased sites the operator should consider spreading topsoil at a depth of 1 m over areas which will not be disturbed by landfill development or on future landfill phases: this soil may be farmed to preserve its structure and fertility.

8.79 The operator should minimise soil loss during storage by

- preventing soil losses into surrounding hedges, watercourses or into a mineral void

- preventing stored soils being contaminated by rubble, windblown litter or fuel oil

- preventing different types of stored materials from becoming mixed.

Soil storage mounds

8.80 The operator should consider the following points with regard to soil storage.

- The location, height and dimensions of the soil storage heaps must be estimated, having regard to the storage requirements of the different soil types.

- Subsoil may be stored in higher mounds than topsoil and may be used for screening.

- Storage areas may need to be extensive to accommodate all soil reserves and must be indicated in the soil movement plan.

- Storage areas should be stripped of any more valuable materials first, for example topsoil should be stripped from subsoil storage areas.
- Only machinery which is used to construct the storage mounds, and remove soil from them, should be allowed to run over the mounds.
- Soil storage areas should be fenced to prevent contamination or improper use.
- Storage mounds should be sown with grass.

Soil replacement

8.81 Soil replacement must follow the same guidelines as soil stripping. The operator must ensure that

- soils are replaced in the correct sequence
- soils are spread to the correct thicknesses
- works are organised to cause minimum compaction to replaced soils.

Figure 8.3 shows soil replacement techniques: illustrations B and C cause least vehicle movement over spread soils and therefore minimise compaction[66].

8.82 The timing of soil replacement works is important. Soil spreading must be completed early enough to enable cultivation and vegetation establishment to take place before the onset of winter: see paragraphs 8.48 to 8.56.

Alleviation of soil compaction - subsoil ripping

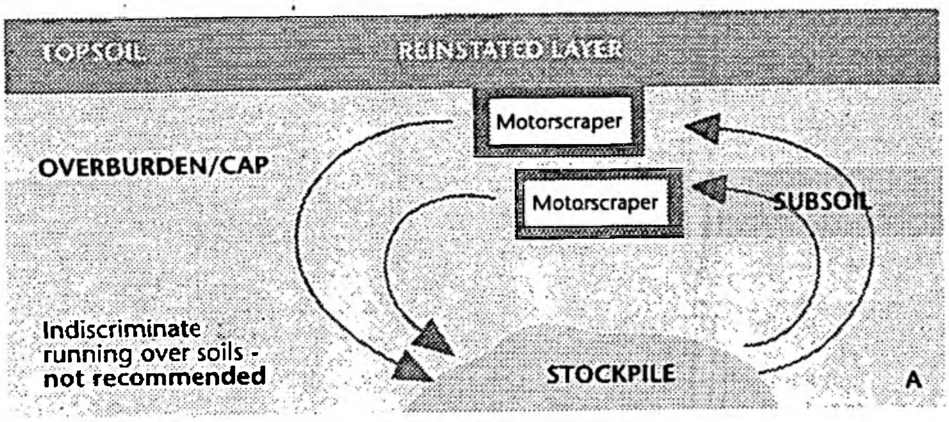
8.83 The compaction caused by soil handling machinery running must be alleviated by subsoil ripping. This may be carried out by either of the following methods:

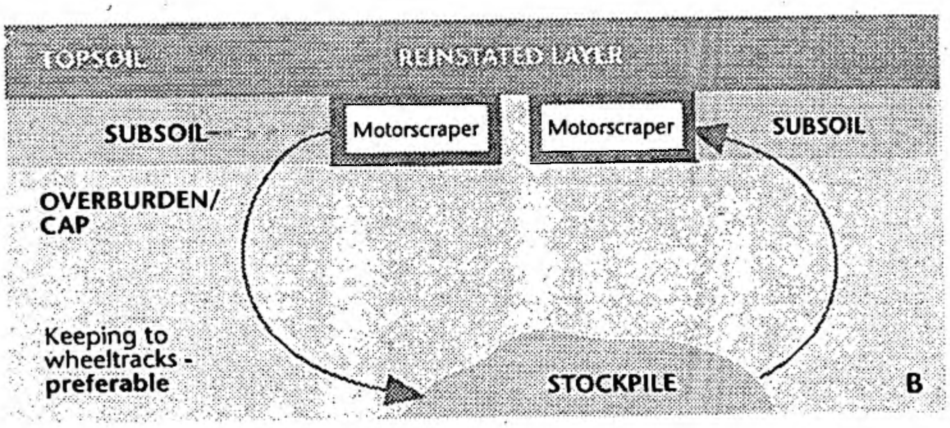
- sequentially as soils are replaced by implements working at a relatively shallow depth, to loosen the compacted layers caused by the front wheels/tracks of the machinery
- by deep ripping the entire profile after soil placement.

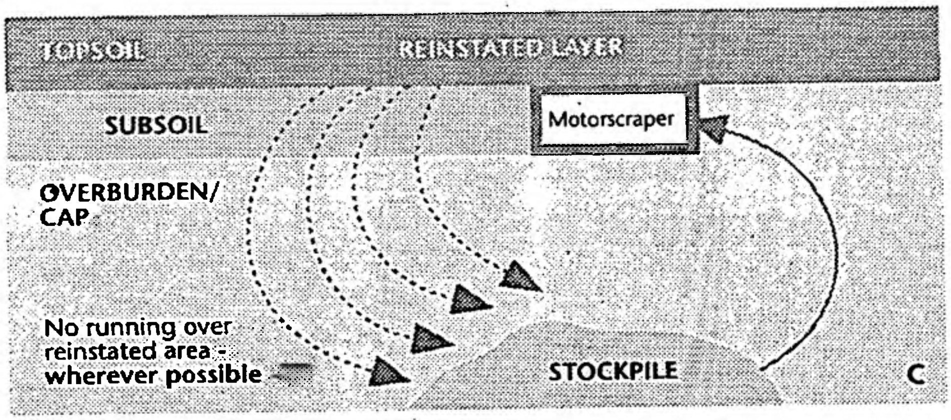
8.84 Preparations should be carried out when the soil is in the best condition for loosening, i.e. dry to slightly moist.

[66] See also Appendix A.

Figure 8.3 Soil placement techniques







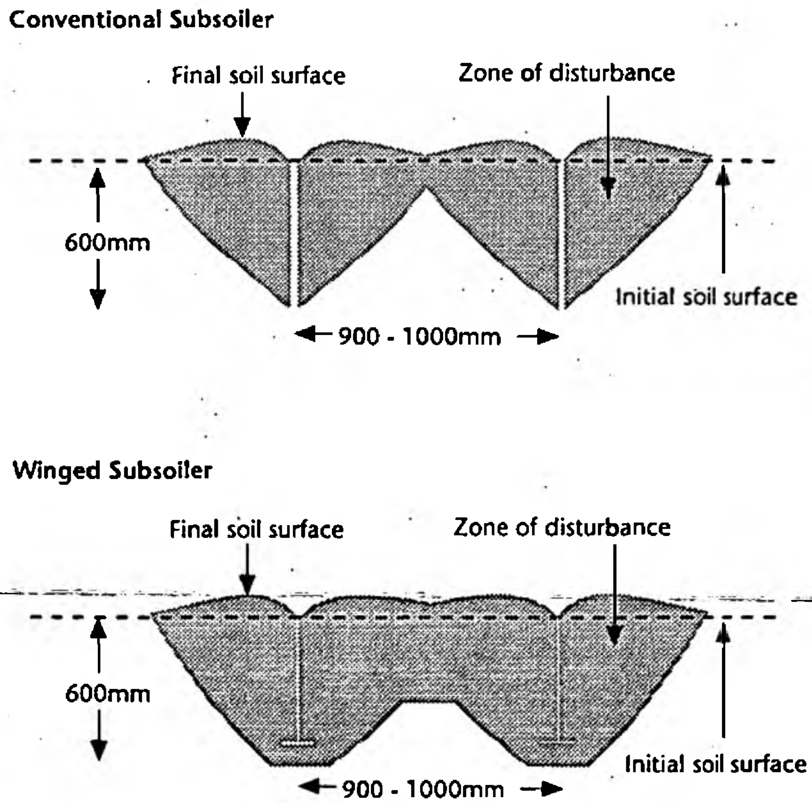
8.85 Ripping is carried out using equipment with up to 5 ripper tines fixed on a frame. To achieve the required depth of up to 600mm, this should be drawn by a tracked machine such as a D6 Caterpillar tractor. Where possible an implement fitted with `wings' should be used. There may also be advantages in using a series of tools either sequentially or mounted on a tool frame which loosen the soil to progressively greater depths. Periodic checks must be made that the required depth is being achieved.

8.86 The depth of working and spacing between tines should be determined by observations of preliminary runs; as a rule of thumb a spacing of about $1^1/_2$ times the depth of working is normally recommended: see Figure 8.4. Care must be taken to ensure that subsoil ripping will not interfere with gas control systems.

8.87 Subsoil ripping may be carried out by

- a single pass with closely spaced tines, or
- repeated passes, with wider spaced tines, either parallel or at an angle to earlier passes.

Figure 8.4 Subsoil ripping during restoration



The direction of ripping should be at 45° to the contours for most effective soil drainage. Subsoiling should be carried out when the soil is dry or moist to the full depth of working. Subsoiling wet soil cuts a channel and smears the soil but will not effectively lift, fracture and loosen the soil.

8.88 If underdrainage will be installed, it should be considered at this stage because subsoil ripping across drainage lines will give more effective drainage than either subsoiling or underdrainage alone. Where possible, the subsoiler tines should be drawn from or into ditches.

8.89 Repeated subsoiling may be necessary during soil placement if it is intended to install underdrainage, and during aftercare to relieve compaction caused within the reinstated soil profile.

Stone-picking

8.90 Any large stones (>100mm diameter in the topsoil, or 200mm diameter in the subsoil) brought up by subsoil ripping or present in the restored soil should be removed.

8.91 Larger stones brought to the surface should be removed by hand or raked by an excavator bucket fitted with teeth into rows for easier removal. Specialised stone-picking machinery, or stone rakes, are also available. These remove stone from the top 150-250mm of the soil and work it into rows, from where it may be removed by a stone elevator.

Cultivation equipment and techniques

8.92 The two main objectives of cultivations are to

- bury weeds and vegetation residues
- break the soil down to a sufficiently fine tilth for germination and root growth.

8.93 The soil should be cultivated enough to produce a reasonably fine tilth. Excessive cultivations, especially if carried out when the soil is wet, cause as much damage to soil structure as soil moving machinery and should therefore be avoided.

8.94 Cultivations are generally carried out using heavy duty agricultural equipment. Mould-board ploughs, which invert the soil, should not be used on shallow restored topsoil: they invert the topsoil, burying it under subsoil. Chisel ploughs and heavy rigid tined harrows loosen the surface soil. They do not invert soil or bury weeds and vegetation and should only be used where weeds are absent or treated with herbicides. Spring or coil tine harrows, spike harrows or discs are also used to cultivate the soil. The seedbed preparation is usually completed using a chain harrow to incorporate both fertiliser and seed.

8.95 Powered rotary cultivators (Rotavators) are popular because a seed-bed may be prepared in a single pass, but their pulverising action makes them unsuitable for recently restored land. Rotavators may create a hard pan beneath the zone of worked soil which impedes drainage and root growth. Powered harrows, either reciprocating or rotary, are also used for rapid tilth production. They do not produce such a sharply defined hard pan, but pulverise the surface soil like a conventional Rotavator.

8.96 Rollers, either plain or ribbed (Cambridge), have a similar, but gentler, action to discs. Ribbed rollers are used to finish seedbeds and to firm the soil around recently sown seed to promote germination. Plain rollers should be used with care as they can cause surface compaction.

Soil amendments

8.97 Soil testing will reveal whether soil amendments are necessary to establish the intended cropping or planting. Soil amendments include

- *lime* - normally used only on agricultural land to adjust the pH to the optimum 6.0 for grass or 6.5 for arable crops
- *organic manure (farm-yard manure)* - provides both nutrients and organic matter, but is difficult to handle and only of localised availability. It should be used to increase organic matter levels. In some areas other manures may be available such as poultry manure and composted green waste: their availability and use should be investigated, taking MAFF advice on suitability and application rates.
- *sewage sludge* - may be useful providing additional organic matter and nutrients. It is available as i) dried or semi-dried cake, and ii) a wet slurry. It must be applied with special equipment and conform to the regulations[67]. Suppliers or MAFF will advise on application rates and procedures.
- *inorganic (artificial) fertilisers* - widely used to increase soil fertility for agricultural crops, less frequently for trees and amenity planting. They include both straight fertilisers containing only a single nutrient (nitrate, phosphate or potash) and compound fertilisers containing mixtures of nutrients in various proportions for common agricultural situations.
- *composted green waste* - becoming more widely available through waste recycling schemes.

[67] Sludge (Use in Agriculture) Regulations 1989 amended 1990.

Chapter 9

Agricultural restoration and aftercare

Introduction

9 This chapter describes the techniques used to establish and maintain agricultural after-uses on restored landfill sites. It is intended to assist the operator, his contractors and land manager or agricultural tenant.

9.2 The chapter covers the following aspects.

- Opportunities for agricultural after-use: paragraphs 9.5 to 9.15
- Specification for agricultural restoration: paragraphs 9.16 to 9.26
- Choice of crops and seed mixtures: paragraphs 9.27 to 9.44
- Cultivation and crop establishment: paragraphs 9.45 to 9.48
- Agricultural infrastructure - drainage, hedges, fences and access tracks: paragraphs 9.49 to 9.78

The potentially adverse effects of the gas control system on agricultural after-use are described in paragraphs 9.7 to 9.15.

9.3 The scope for integrating agriculture with other after-uses, such as nature conservation and woodland, is also examined.

9.4 References to the published information and sources of information and advice on this after-use are provided in Appendix J.

Opportunities for agricultural restoration

9.5 The opportunities for agricultural restoration depend on the following.

- Planning requirements, particularly on new greenfield sites, to safeguard high quality land.
- Requirements of the landowner.
- Acceptability to local farming community: low grade land, or land in an unfavourable location may not be viable.
- The availability, on site preferably, of adequate good quality topsoil and subsoil for restoration.
- Design and installation of the gas control system.

9.6 The critical factors to be considered when choosing whether the site should be restored for agriculture are described in Chapter 4. If the operator is considering an agricultural after-use, he must be confident that the restoration will be able to support the cropping regime expected by a tenant, landowner or planner.

- Poorly executed restorations, and well executed restorations with unfavourable soil conditions, can result in restored land where
  - arable cropping is only marginally possible
  - maintaining a satisfactory grass sward is difficult.

This situation is often encountered on sites where most of the original soils have been lost. The operator and planning authority should question whether agriculture is the most appropriate after-use, and examine the feasibility and acceptability of alternative after-uses.

Landfill gas control systems - effects on agriculture

9.7 In most cases, unless the gas control system is carefully designed it will potentially have very severe consequences upon agricultural practices.

i Common gas design features which affect agriculture

9.8 Gas control systems commonly have gas wellheads in a more or less regular pattern at 40 - 60 m spacing over the whole site. Some gas system designs bring the pipework into the vertical well at a depth of 600mm which is the same as the subsoil ripping and agricultural drainage depth.

9.9 If the gas control system has ground level or above-ground gas wells which are located in the fields, these will seriously affect arable farming practices, leading to

- loss of cropping area
- damage to cultivation and harvesting equipment
- damage to gas installations, resulting in further disturbance for repairs.

The operator should mark these features so that they are visible above the standing crop.

9.10 Although the loss of land due to the gas infrastructure is very small, less than 1% of the site area, significant loss of productivity may result from

- crop loss
- trafficking for access and remedial works
- retardation of growth as a result of piecemeal reinstatement.

9.11 The loss of productivity in pasture is not usually very great, although the need for regular access for monitoring may cause some disturbance. More significant losses occur in grassland cut for hay or silage because machinery must work around ground level or above-ground wellheads.

- Agricultural contractors may charge up to 30% extra over normal costs for working in grassland fields with obstructions every 40 m.

9.12 The effect of gas systems on arable cropping can be so serious as to render the land unworkable.

- Farm equipment is not suited to working in small awkwardly shaped areas: unless wellheads are spaced in a very regular grid pattern, at a spacing which suits the width of the farm `tramlines', the amount of unfarmable land may be up to 50% of the area.

9.13 Corridor cropping is the only realistic alternative, with the access areas along each line of wells being kept under grass. This arrangement may lead to weed and disease infestation of the crop. Corridor cropping may also become untenable if the arrangement of the wellheads cannot be kept to a regular grid, because of

► constraints of contours and gas drainage

► the need for additional wells.

ii Ways of reducing impact

9.14 The impact of gas systems on agriculture can be greatly reduced by

► design: see Chapter 6

► the timing of final restoration and aftercare: see Chapter 7.

9.15 The operator is strongly advised to consider the design of the gas control system *at the same time* as the restoration and aftercare design where the site is to be restored for agriculture. He should also discuss a strategy of interim restoration with the planning authority: see paragraphs 7.18 to 7.25.

Specification for agricultural restoration

9.16 The specification for agricultural land is now described.

- Landform and drainage: paragraphs 9.17 to 9.21
- Soil requirements: paragraphs 9.22 to 9.23
- Organisation of agricultural operations: paragraphs 9.24 to 9.26.

Landform and drainage

9.17 The post settlement landform of a restored landfill site must

- ► be acceptable in landscape terms
- ► have gradients which do not adversely affect the proposed after-use
- ► provide effective site drainage.

Landform design aspects are discussed in Chapter 6.

9.18 Recommended minimum slopes are intended to promote site drainage by assisting surface water run off and to ensure effective operation of the underdrainage system. On undisturbed land underdrainage remains effective at slopes as gentle as 1 in 200, but landfill settlement causes problems with very shallow gradients.

- Minimum gradients of 1 in 25 to 1 in 15 are recommended on landfills which may settle, depending on local soil and climate.

9.19 Differential settlement on flat or gently sloping restored land produces closed hollows. If the soils overlie an impermeable cap or are poorly drained, run-off from the surrounding high spots will collect in the hollows. This severely limits agricultural use. The operator should

- ► carry out interim restoration and subsequently correct the grade with additional soil
- ► improve soil structure and encourage infiltration.

9.20 Arable sites should ideally be designed with a maximum post settlement gradient of 1 in 8. Sites with substantial areas which exceed 1 in 8 are more appropriate as grassland. Gradients steeper than 1 in 3 are too steep for agricultural use: see Table 6.1 for critical slope limits in relation to use.

9.21 The risk of rapid surface run-off and soil erosion increases as slope angle increases. Erosion control measures on steep agricultural land include

- ► carrying out cultivations across the slope to avoid creating downslope channels
- ► maintaining a vegetation cover
- ► promoting good soil structure to encourage infiltration.

Erosion may be controlled on interim restoration areas by leaving windrows of collected (stone raked) stones parallel to the contours to reduce run off and collect eroded soil.

Soil requirements

9.22 The soil factors which determine the success of agricultural production are

- *good drainage* - a permeable profile with no compaction, water drains freely into
  - an underdrainage system
  - drainage layer
  - underlying fill in an uncapped inert wastes site
- *high available water capacity* - water shortage during the summer restricts plant growth in most of lowland Britain, deep moisture retentive soils are best
- *high fertility* - all agricultural crops, including grass, are bred for high fertility conditions: areas intended for productive agriculture need topsoil, fertiliser and lime to maintain high fertility
- *absence of obstructions which would hinder cultivations* - high stone content also reduces available water and nutrients and may hinder seed germination

9.23 The soil profile for agricultural after-use is site-specific and should take into account the amount of available soil. It should specify

- depth of topsoil - usually 100 - 300 mm, depending on the amount of soil available. If imported topsoil is used, the type of topsoil to be imported should be specified
- depth of subsoil - typical requirements are given in Table 8.2. If imported subsoil is to be used the nature of the imported material should be specified
- stone content: see paragraphs 8.87 and 8.88
- profile drainage - depends on the nature of the soil, methods of soil handling: see Chapter 8, including ripping or subsoiling, and the underdrainage: see paragraphs 9.62 to 9.69[68].

Organisation of agricultural operations

9.24 For successful agricultural restoration and aftercare the operator must *organise* and *programme* the work[69]. Soil replacement, cultivations, seeding and subsequent works are all seasonal, and depend on weather and soil conditions, both when undertaking the work and following. Timing is therefore very important: poor timing causes soil damage.

[68] The Application of Drainage Techniques in the Management of Restoration Landfill Sites, W S Atkins.
[69] Restoration of Mineral Workings to Agriculture RPS and Wye College (to be published 1995).

- A vegetation cover should be established on restored soils before the winter because
  - the action of the plant roots will improve soil structure and drainage
  - the crop will protect the soil against erosion on slopes.

See also paragraphs 8.46 to 8.53.

9.25 The operator must make proper provision for on-going agricultural operations. He should appoint a suitably experienced farm manager, contractor or tenant at the start of the aftercare period, if not before, to supervise and co-ordinate the agricultural works. The operator should consult with MAFF when preparing an agricultural aftercare scheme. The planning authority will probably continue to consult MAFF throughout the aftercare period to ensure the scheme is managed correctly and remains appropriate to the site and its locality.

9.26 All new landfill permissions require a formal period of aftercare. On older sites with no legal requirement, it is recommended that a formal aftercare scheme be devised[70]. Government guidance[71] suggests an aftercare scheme should include

- an outline strategy of aftercare for up to 5 years to be agreed before soil replacement is completed
- a detailed programme for the forthcoming farming year to be submitted early enough for it to be agreed before implementation
- annual site meetings between the operator and the planning authority, usually with MAFF in attendance, at which the preceding year's cropping, and proposals for the forthcoming year, are discussed and agreed.

Choice of crops and seed mixtures

Site conditions and after-use

9.27 The main objectives of growing agricultural crops during the aftercare period are

- to assist soil recovery after soil handling operations
- to promote the development of the structure and fertility.

These objectives should take precedence over commercial considerations such as agricultural output and profitability. The operator should make appropriate financial arrangements with the land manager, agricultural tenant or contractor.

[70] See Appendix G.
[71] See MPG 7.

9.28 The main criteria which must be taken into account when choosing an appropriate crop are

- *climate* - arable crops prefer warmer, drier climatic conditions found in lowland areas; grassland is more common in cooler, wetter regions
- *location* - local agricultural regimes (arable, pasture, mixed farming); suitable farming expertise must be available locally, together with a market for the chosen crops
- *soil conditions* - depth, fertility, drainage and soil type; select a crop which is suited to the soil conditions; in the initial years this may be grass which is tolerant of adverse conditions
- *effects of gas control system* - arable cropping is adversely affected by ground level and above-ground wellheads and manholes, requirements for access and remedial works
- *ground cover* - choose a crop which will cover the ground quickly and persist through the winter to reduce soil erosion
- *soil structure improvement* - choose a crop such as grass with an extensive fibrous root system
- *avoidance of soil damage* - choose a crop which does not require field work or harvesting in the winter when damage to restored soils may occur
- *landfill type* - on older sites, where gas migration may occur, grass is more tolerant of landfill gas than most arable crops.

9.29 The following paragraphs describe the main agricultural crops which might be grown on restored land. An indication is given of their suitability for particular circumstances and conditions.

Grass

9.30 Grass is the most suitable agricultural crop for the majority of restored sites, particularly during the aftercare period, because

- it is relatively tolerant of adverse soil conditions, particularly poor drainage
- it provides an all year round protective cover
- it promotes the redevelopment of soil structure
- it is relatively easy to establish and manage, and is less risky than arable crops
- grassland is easier to farm than arable crops on sites with gas and leachate control systems.

9.31 Grass is cut for hay or silage, collectively referred to as `grass for conservation'. Hay may be difficult to market, silage can only be made and used locally. Grazing needs stockproof fencing, a water supply and suitable arrangements to remove the stock in wet weather when they begin to damage the land (poaching).

9.32 Intensively used grassland is based on varieties of ryegrass (perennial, Italian or tetraploid) which are adapted to fertile conditions and high fertiliser inputs. They are normally farmed as leys, that is, temporary swards sown to grass for a limited period (1 to 5 years), often immediately followed by another grass ley. Permanent grass is not regularly renewed and includes swards with over 30% ryegrass which are capable of supporting a heavy stocking rate, and very poor quality pastures similar to rough grazing.

9.33 If the operator or farmer wishes to grow grass on the restored site he must take the following into account.

- *Soil conditions*
    - deep, well drained, fertile soils will allow grass leys, grazed or cut for silage or hay
    - on poorer soil conditions pasture which is infrequently renewed, grazed or cut, based on a mixture of ryegrass, timothy, cocksfoot, fescues and clover should be chosen
    - on very poor soil conditions a productive grass sward will require fertilisers, regular subsoiling and recultivation of the sward to add organic matter to the soil; low productivity grassland may be more cost-effective
- *Utilisation* - whether the grass is to be grazed, cut for silage or hay and how frequently the grass ley will be renewed. Long leys and permanent grass are based on persistent varieties such as perennial ryegrass, cocksfoot, timothy and meadow fescue; less persistent varieties such as Italian ryegrass are suitable for short term leys.
- *Nitrogen source* - highly productive leys tend to rely on artificial nitrogen fertilisers, but longer leys and permanent grass mixtures often include clover to fix atmospheric nitrogen for the benefit of the whole sward.

9.34 Grass and clover are sown in spring or late summer/early autumn; typical seed rates are 40-50 kg/ha depending on the seed mixture. If there is enough moisture the seed is broadcast, alternatively, especially in drier conditions, the seed is drilled. Following sowing, the land is generally rolled to give good seed-soil contact, taking care not to over-consolidate the soil, especially when seeding directly into subsoil.

9.35 Subsequent operations include fertiliser applications, mainly nitrogen - except where there is clover in the mixture, and spraying or cutting to control weeds.

9.36 Grass is a suitable agricultural option everywhere except in areas such as the edge of towns or arable farming areas. It is particularly suited to poorly drained soils including those where underdrainage has not been installed or where there is soil compaction.

Arable crops

9.37 Arable cropping on restored land is usually based on cereals (wheat or barley), preferably autumn sown, when ground conditions are more likely to be favourable, which can provide some protective cover over the winter. Oilseed rape may also be grown on well restored sites, also less common crops like maize, potatoes, beans, peas or other vegetable crops. These crops should generally be avoided, however because

- they require more complicated growing techniques
- they are less tolerant of adverse conditions
- they increase the risk of soil damage because they are harvested late.

Winter wheat

9.38 Winter wheat is one of the most suitable arable crops for restored land. It prefers a medium to heavy textured, well drained soil, with a pH above 5.5 and moderate fertility. Restored land is generally suitable for feed wheat varieties rather than for milling.

9.39 It is normally sown with a seed-drill between late September and early February (October is best): seed rates of 125-200kg/ha are typical. Fertiliser and pesticides applications are made in the following Spring which is assisted by the creation of `tramlines' at regular spacings through the crop determined by the width of the fertiliser and spraying machinery in use. These tramlines may be arranged to suit lines of landfill gas wells to minimise loss of capping. The crop is usually harvested by combine harvester in August and September.

Winter barley

9.40 Winter barley may be grown on lighter, freely draining soils of average fertility and a pH around 6.5 or above. Cultural requirements are similar to winter wheat. Sowing is typically at seed rates of 150-180 kg/ha between late September and mid-November. Harvesting is usually July and early August. Restored land is generally only suitable for feed varieties rather than malting varieties.

Other crops

9.41 Other cereals, such as oats and rye, may also be grown where soil conditions are not suitable for wheat or barley. Crops such as oilseed rape, linseed and vegetables are not usually successful on restored soils. Root crops (potatoes and sugar beet) are harvested in the autumn when damage to restored soil structure is likely and are therefore not recommended. Fodder crops (forage rape, swedes) are eaten in the field during late autumn; grazing animals cause severe soil damage and these crops are also not recommended.

Varieties, seed mixtures, seed source and quality assurance

9.42 There is a wide choice of crop varieties and seed mixtures (in the case of grass) to suit particular situations. New varieties regularly appear on the market, usually bred for conventional high input/high output agriculture. The choice should be guided by an agricultural adviser, giving special attention to persistence and hardiness, rather than high productivity.

9.43 For grassland the choice of the correct seed mix, and whether or not to include clover, depends on the

- future use of the land
- the length of time the grass is to be left down
- the soil conditions.

Professional advice should be taken with due regard to the objectives of the proposing cropping regime and the prevailing site conditions.

9.44 Seed should be purchased from a reputable seed merchant, to ensure its high quality. Seed merchants are bound by legislation and must conform to quality assurance codes set by trade organisations.

Cultivations and crop establishment

9.45 The choice of cultivation equipment depends on soil conditions: see Chapter 8. Cultivations should produce a sufficiently fine seedbed for the particular crop, without damaging the soil structure. Rigid, coil and spring tine harrows, discs and chain harrows should be used.

9.46 Cultivations should ideally be carried out when the soil is moist to dry, and should be delayed if the soil is very wet. This is particularly important in clay soils when significant damage to soil structure results if the soil is worked when wet. It is important to carry out only those cultivations which are necessary to produce a satisfactory seedbed. Excessive passes with equipment to achieve a fine, smooth surface for aesthetic reasons are unnecessary and damage soil structure.

9.47 Nutrient deficiencies and imbalances should be identified by soil sampling and analysis[72] Advice is available on fertiliser applications[73], and relates to crop, time of sowing, soil type and soil nutrient index values. Fertilisers are applied either

- during the cultivation operations, or
- simultaneously with sowing the seed.

A compound fertiliser containing nitrogen, phosphate and potash is usually added at the time of sowing. Straight nitrogen fertiliser is usually applied as a top dressing in spring and intensively managed grassland may receive several applications.

[72] Sampling Soils for Analysis, MAFF Leaflet 655.
[73] Fertiliser Recommendations, MAFF Booklet GF24.

Pest control

9.48 A wide range of pesticides is approved for use in agriculture, with guidance laid down for their specific use, application rate and safety precautions to be observed during use. Operators are advised to check that their maintenance contractors are aware of, and comply with, the legislation[74]. This must be strictly adhered to in the interests of safety and for environmental protection. Only contractors who have successfully completed an approved pesticides training course may apply pesticides on land belonging to a third party.

Agricultural infrastructure

Drainage systems

9.49 Agricultural drainage should be considered at the design stage. It should form part of the overall strategy for water management on the site, including controlling the amount of water arriving at the landfill cap[75]. It will usually be a condition of the planning permission, although the detailed scheme may be approved during the aftercare period following consultation with the LPA and Environment Agency.

i Relationship between landform and site drainage

9.50 Drainage provides a means to remove excess water from the soil, by open ditches or an underdrainage system. Underdrainage is normally accompanied by secondary treatments to encourage soil water to soak into the drains. This may include permeable backfill to the pipe system, mole drains or subsoiling.

9.51 The final landform should integrate with the surrounding land (see Chapter 6) and also ensure satisfactory site drainage. The minimum slopes necessary for satisfactory site drainage are site-specific and are determined by

- ► type of landfill (capped or uncapped)
- ► surrounding surface watercourses
- ► soil type
- ► climate
- ► intended after-use.

9.53 Drainage proposals should include details of

- surface drainage ditches (if any), their integration with the adjacent watercourses, and their compatibility with the proposed field layout
- underdrainage system design, in particular where the drainage outfalls are located.

[74] The Control of Pesticides Regulations 1986 and the Control of Substances Hazardous to Health Regulations 1994 (COSHH).
[75] The Application of Drainage Techniques in the Management of Restored Landfill Sites, W S Atkins.

9.54 On sloping sites, where the soil is compacted or poorly structured, surface water run-off may cause erosion. Erosion risk is greatest

- in areas of high (and intense) rainfall
- where soils have poor structure and/or are slowly permeable
- where the slopes are steep, encouraging rapid runoff[76].

Erosion control measures include cut-off ditches and french drains, geotextiles and vegetation establishment.

9.55 Drainage methods for agricultural restoration and aftercare include:

- surface drains, to collect run-off and discharges from the underdrainage system
- piped underdrainage, usually with permeable backfill
- secondary drainage treatments including subsoiling and mole drainage.

9.56 The main advantages to be gained from drainage are

- improved crop growth
- alternate wetting and drying helps to promote soil structure development
- longer period of time when the soils are in a suitable condition for farming operations without risk of damage to soil structure.

ii Surface drains

9.57 Figure 9.1 illustrates the various kinds of surface and underground drains which can be used on landfill sites. Surface drains include open ditches, cut-off ditches, french drains and temporary surface water arrangements.

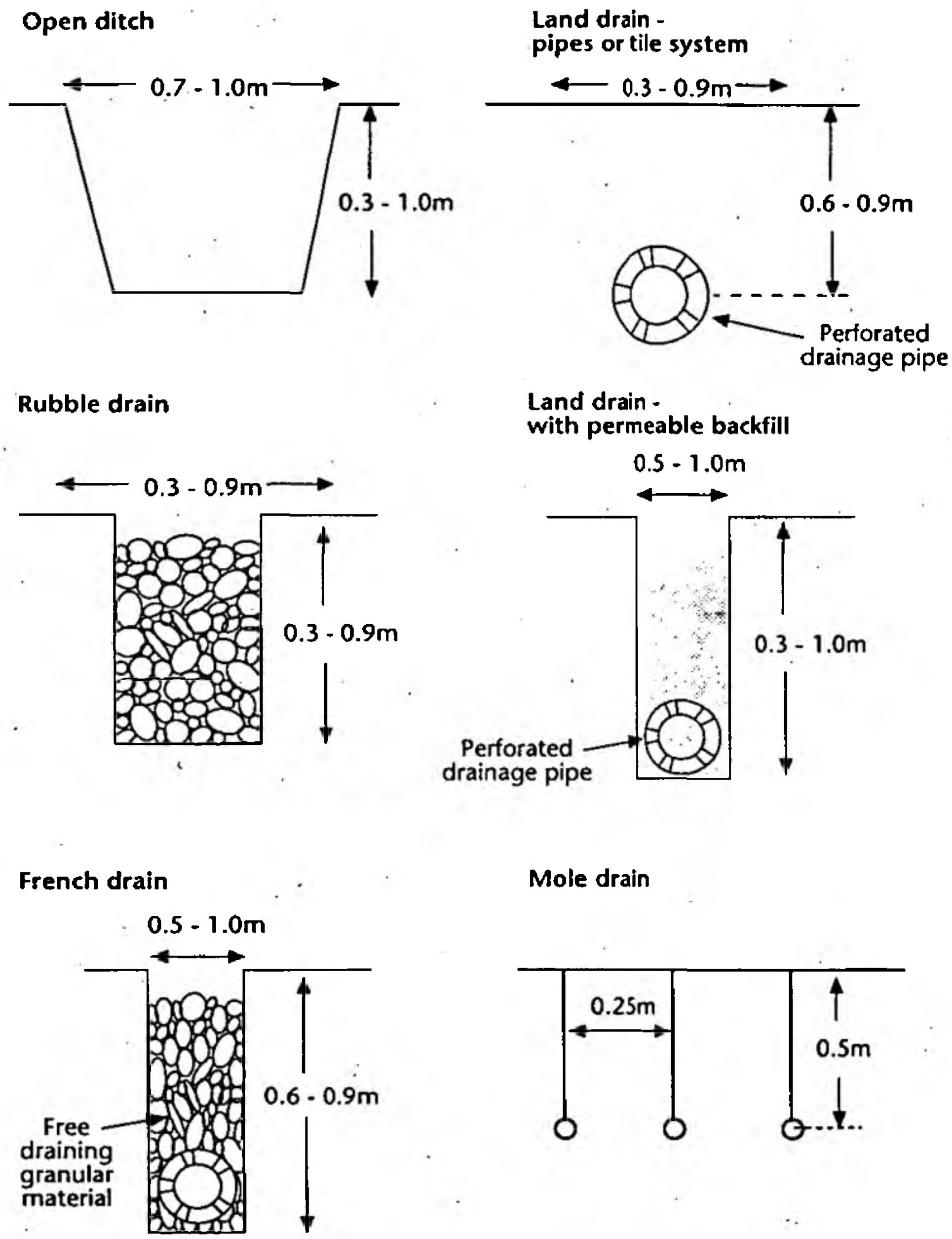
9.58 On restored landfill sites open ditches are most useful as a means of connecting site drainage to surrounding surface water courses. They should be designed to accept the anticipated outflows from underdrainage systems and any surface run-off. They should be checked regularly and cleaned out if flow is impeded by vegetation, collapsed sides or other obstructions.

9.59 Open ditches, often with hedges, are used to mark field boundaries. Suitable crossing points for site traffic must be provided.

9.60 Rubble drains consist of a trench filled with gravel, which may have a pipe at depth (french drain). Traffic and livestock can cross these at will. They are more expensive to construct than open drains but need less maintenance.

[76] See WMP26B, Chapter 6 for information on site drainage.

Figure 9.1 Drainage systems



9.61 It may be necessary to include a retention pond (or ponds) in the surface water drainage design to store excessive run-off during times of heavy rainfall. They should be designed to release water to the local watercourse at a rate equivalent to normal agricultural run-off: this arrangement would need the approval of the Environment Agency. Retention ponds allow suspended solids to settle out of the discharge water prior to their release. They can also be designed and managed for wildlife.

iii Piped underdrainage systems

9.62 The need for piped underdrainage should take account of

- the restored landform and the presence of an impermeable or slowly permeable capping layer
- the need to reduce infiltration into the fill or arriving at the capping layer
- the soil types, particularly their permeability
- the intended long term after-use.

Unless the soil and underlying waste are freely draining, underdrainage is needed

- on soils replaced by motorscraper
- on heavy textured soils
- on restored land intended for arable cropping and high productivity grassland.

It is rarely necessary to install underdrainage on land intended for low-intensity grazing, amenity or woodland.

9.63 Underdrainage should be installed as early as possible, preferably in conjunction with soil placement and any subsoiling/ripping operations. Where considerable settlement is anticipated, it may be preferable to wait until initial settlement has taken place before incurring the expense of underdrainage. If this is not possible, a skeletal, sacrificial system should be installed, to be followed by a permanent system in due course.

9.64 The operator should seek specialist advice on the design of the drainage system. Due allowance should be made for the conditions of the restored soils, which may differ from undisturbed soil of the same type. The depth at which drainage pipes are placed must be above the level of any gas control pipes.

[50] See WMP26B Chapters 6 and 9 for more details on leachate systems.

iv Secondary treatments to help drainage

9.65 The two commonest forms of secondary treatments are **subsoiling** and **mole drainage**. Secondary treatments encourage water to pass through the restoration profile into the underdrainage system by

- loosening the soil
- removing compaction
- improving permeability.

The need for secondary treatments will be site specific and should be discussed at the annual aftercare site meetings.

9.66 Subsoiling is similar to the ripping operations described in paragraphs 8.83 - 8.89. To assist underdrainage, subsoiling should run across the drainage lines, taking care not to disrupt the backfill excessively. This method is particularly appropriate where there are compact layers within the soil profile. It should be carried out when the soil is moist or nearly dry for best effect.

9.67 Mole drainage consists of drawing a metal plug (or mole) through the soil to create a drainage channel which connects into the permeable backfill above the drainage pipes. It is only suitable in soils with a high clay content. Moling is most effective when the soil is slightly moist, in spring or late autumn.

v Maintenance

9.68 All drainage systems should be regularly inspected and maintained, particularly outfalls and surface water ditches. Full records of underdrainage systems and any modifications to them should be kept with the restoration working plan.

Fences and hedges

9.69 Fences and hedges are used to

- mark field boundaries
- provide stockproof barriers
- provide landscape features, especially hedges: see Chapter 6
- provide wildlife habitats and corridors: see Chapter 11.

i Fences

9.70 Three main kinds of fencing are commonly used on agricultural land:

- post and wire - depends for its efficiency on the tautness of a series of horizontal wires between well anchored straining posts

- stockproof - depending upon the height and style of mesh, this may also be rabbit-proof or deer-proof; barbed wire should be replaced by plain wire along footpaths and areas of public access

- post and rail - constructed from timber rails fastened to sawn or half-round timber uprights.

The operator should consult the British Standard for Fencing BS 1722 for information on materials, fencing styles and construction.

9.71 Access points to fields through fences or hedges should be fitted with gates. Steel gates may be preferable to timber gates in some locations.

ii Hedges

9.72 New hedges are expensive to plant and establish, being twice as expensive per unit length as a stockproof wire fence. Grants of up to 60% may be available[77]. Maintenance is needed for up to 10 years after planting. Thereafter they can be trimmed, laid or otherwise managed to suit local practice.

9.73 Hawthorn and blackthorn are the most common hedgerow species, and hornbeam, maple, crab and hazel may be planted as standards to grow into hedgerow trees. Species diversity may be increased by adding up to 5% of other species e.g. dog rose, guelder rose, field maple, holly and privet.

9.74 A typical planting specification would be 5 two-year transplants (450-600mm high) per metre of hedge, planted in a staggered row into a cultivated strip 600mm wide by 300mm deep. The saplings should be planted with the roots well spread before covering with soil. After planting the new hedge should be fenced on either side for protection against grazing animals, rabbits and hares.

9.75 Longer term maintenance consists mainly of cutting on a 2-3 year cycle, preferably in December, January or February so as not to affect wildlife. An A-shaped hedge, 1.5 to 2.0m high and 2.5m wide at the bottom, is generally considered best for wildlife, while a shelter hedge is generally cut taller with straighter sides.

Water supplies

9.76 Supplies of fresh drinking water are essential for grazing livestock. This may be available from ditches and ponds, but is more reliably supplied by pipe to a trough.

9.77 If the operator wishes to irrigate the restored site he should ensure that

- it does not conflict with the water management objectives of the landfill

- a reliable source of water is available: an abstraction licence may be necessary

[77] Grants administered by Countryside Commission (Countryside Stewardship Scheme) soon to be transferred to MAFF, County or Metropolitan Borough Councils (Landscape Conservation Scheme) Forestry Authority (Farm Woodland Grants Scheme) - see Appendix H.

- there is a means of bringing it to the area being irrigated (e.g. by tractor mounted pumps)
- there is a means of application such as hose-reel self travelling system with a rain gun.

Farm access tracks

9.78 Farm access tracks should be integrated with the access requirements for gas and leachate maintenance, monitoring and control systems. Routes along field headlands are preferable to those across the centres of fields.

- Lightly used farm tracks can be unsurfaced, but these may need regular maintenance to repair ruts and hollows which will inevitably form.
- More durable tracks can be constructed relatively cheaply using suitable rubble brought to site or, if the landfill is linked to a mineral extraction site, by waste materials from that operation.
- Imported materials such as gravel, crushed rock, chalk or road scalpings are more expensive.
- Bitumen surfaced tracks are rarely necessary.
- Purpose-designed geotextiles are available which can be used to form access tracks, some of which will allow grass to be grown on tracks which are not subject to heavy use.

Other considerations

Farming for nature conservation

9.79 The operator should consider combining an agricultural after-use with opportunities to enhance the nature conservation value of the site. Restoration for nature conservation is described in Chapter 11: some of the techniques described in that Chapter may be applied to a principally agricultural restoration.

9.80 Some ways in which nature conservation can be promoted on agricultural land include

- planting new hedges (see paragraphs 9.70 - 9.74) and maintaining new and established hedges around the site for nature conservation purposes
- encouraging hedgerow trees
- planting small areas of farm woodland: see Chapter 10
- managing field margins for nature conservation.

9.81 Field margins typically consist of three elements, the boundary, the crop edge and the boundary strip: see Figure 9.2. The boundary strip can be managed as a "conservation headland" for wildlife.

- encouraging wetland areas on the edges of the site or on those parts of the site either not landfilled or filled only with inert wastes

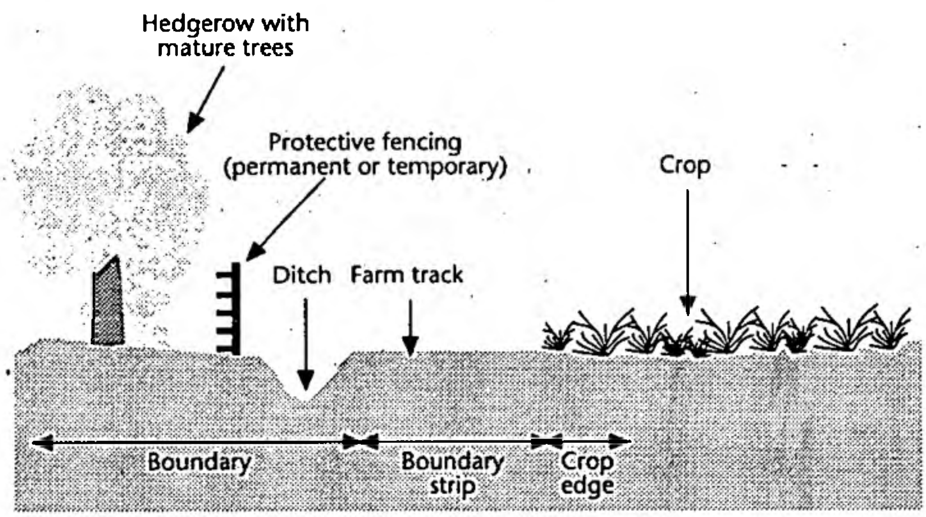
- avoiding excessive use of fertilisers and pesticides.

Farming and public access

9.82 Public access to farmland, whether on restored landfills or not, can cause problems. As a general rule it is best to encourage the public to use public footpaths and other designated routes, by providing signs, styles, gates and keeping paths clear.

9.83 Areas of the site from which the public must be excluded for safety reasons should be securely fenced. Landscape design features, such as planting and clearly indicated routes and areas for public access, can also help to discourage the general public from certain areas of the site

Figure 9.2 Managing field headlands for wildlife



Chapter 10

Tree planting and woodland restoration and aftercare

Introduction

10.1 Some landfills are suitable for extensive mass tree planting, creating a woodland after-use. Others, particularly those that have taken biodegradable wastes, may be more appropriately restored to an alternative after-use, with limited tree and shrub planting, sufficient to give landscape integration. The restoration design must be developed to suit the individual characteristics of each site.

10.2 This chapter examines the shift in informed opinion towards a more general use of trees in landfill restoration. It also describes the techniques used to establish and maintain individual trees and woodland on restored landfill sites. It covers hedgerows, copses, shelterbelts and woodland.

10.3 The chapter (see also paragraphs 2.39 to 2.46) is directly relevant to both the operator and the LPA in

- ► deciding whether it is appropriate to plant trees or establish woodland on the site
- ► reviewing the tree planting design and the programming of planting works
- ► assessing the interaction between the tree planting proposals and pollution control measures, and resolving potential conflicts.

10.4 The chapter offers advice on

- opportunities for tree planting and woodland: paragraphs 10.6 to 10.21
- requirements for tree establishment: paragraphs 10.22 to 10.41
- choice of species, planting and establishment: paragraphs 10.42 to 10.57.

10.5 References to published information and to other sources of information and advice on this type of after-use are provided in Appendix J.

Opportunities for tree planting and woodland

10.6 A survey commissioned by the Department of the Environment in 1992 showed that tree planting had been successful on landfills. Imperfect landfill construction, in particular

- ► poor gas control
- ► poor restoration practice

has produced conditions on many sites which are too hostile for acceptable tree growth. This has led to the common perception that trees are difficult to establish on landfills.

Further guidance

10.7 Landfill restoration guidance[78] advised against planting trees on modern containment landfill sites, because it was believed that

- tree roots could penetrate the landfill cap, allowing ingress of water and hence increased leachate production
- tree roots could dry out clay caps which would then shrink and crack
- tree roots entering landfill would be adversely affected by landfill gases and high temperatures within the fill
- trees on landfill sites were likely to be susceptible to windthrow which might expose or rupture the cap.

Reasons for reconsidering

10.8 This advice is being reconsidered (1996) because

- limiting the choice of after-uses and flexibility of landfill restoration design reduces its credibility as a sustainable means of waste disposal
- changes in agricultural practices mean that agriculture may not always be the most appropriate after-use
- the Community Forest movement reinforces the general public perception that lowland tree planting should be encouraged
- tree planting enables more interesting and natural landscape design, thus improving the public perception of landfill.

New research findings summarised

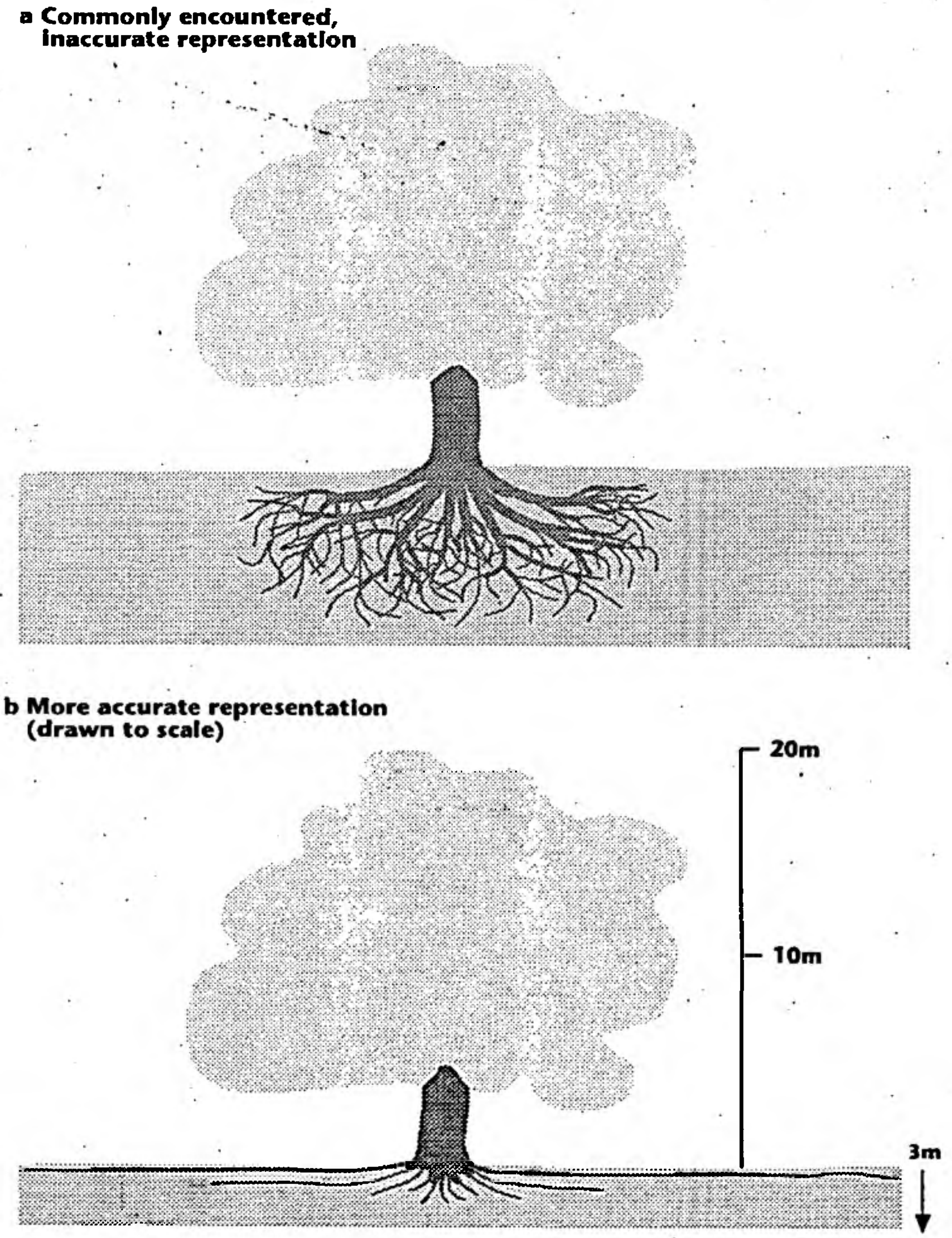
10.9 Recent research, commissioned by the Department of the Environment and carried out by the Forestry Authority, has investigated the rooting pattern of trees and the potential for woodland establishment on landfill. It suggests that, providing certain precautions are taken, the previous advice was over-restrictive and should be revised[79]. The research conclusions may be summarised as follows.

- A well constructed clay cap forms an effective barrier to root growth due to its compaction, anaerobic conditions and infertility; tree roots do not exert enough pressure to puncture or tear synthetic (HDPE) capping materials.
- Tree roots do **not** cause desiccation cracking in a clay cap because they **cannot** extract enough moisture from the clay for significant shrinkage to occur.

[78] WMP26 Landfilling Wastes (1986).
[79] The Potential for Woodland Establishment on Landfill Sites, M C Dobson and A J Moffat.

- Mature trees however probably reduce infiltration into landfill by intercepting rainfall and by taking up and transpiring soil water.
- If the cap is well constructed[80] landfill gas, leachate and high temperatures will not adversely affect plant growth.
- The main reasons for poor tree growth on restored landfills are soil compaction, waterlogging, drought, shallow soil and poor soil quality.

Figure 10.1 Tree root architecture



Source: The Potential for Woodland Establishment on Landfill Sites

[80] Recommended bulk density of an engineered clay cap is 1.8-1.9 g/cm^3; see WMP 26B.

- The roots commonly extend no deeper than 1 to 2m. About 90% of all roots, including virtually all the larger roots, are found in the upper 1m of the soil.

10.10 Increasing stringency in cap construction and gas control have greatly reduced the problems of tree establishment and continued growth. Given suitable restoration standards, particularly adequate soil depths, trees can be grown on landfill sites without compromising pollution control measures.

10.11 The operator and the LPA must carefully evaluate the purpose and extent of tree planting, having regard to

- the age of the site and the nature of the fill
- the pollution control systems
- the character of the site's surroundings.

10.12 Woodland planted on landfills can be managed for a number of purposes, including

- landscape integration
- landscape improvement
- nature conservation
- amenity and recreation
- timber production.

10.13 Operators intending to plant trees or create woodland on any landfill should consider using the scoring system developed by the Forestry Authority[81].

Landscape integration

10.14 On many sites in both rural and urban locations, the principal objective of tree planting is landscape integration. This usually requires hedgerows, individual trees and relatively small areas of tree and shrub planting.

- **Landscape integration objectives can be met on all types of landfill, including those with an impermeable cap and landfill gas control systems.**

10.15 Where the surrounding landscape contains woodland a restored landfill without trees appears stark and unnatural. More extensive tree planting, including woodland establishment, may be carried out on sites which have taken predominantly inert construction and demolition wastes. Tree planting may also be a suitable after-use on older sites where biodegradation is almost complete and settlement and gas production have virtually ceased.

[81] Site Capability Assessment for Woodland Creation on Landfills. Dobson, M C and Moffat, A J, Forestry Authority Research Information Note 263, 1995, obtainable free of charge from Forestry Authority.

- **However, extensive areas of tree planting on sites with landfill gas control systems may not be an appropriate solution.**

Landscape improvement

10.16 Where agricultural practice has resulted in hedgerow and woodland removal, landfill restoration provides an opportunity for its replacement.

- Hedgerows and hedgerow trees, small copses in field corners, screen planting and mass planted areas contribute to landscape improvement.

Trees can be planted in areas which are unsuitable for other uses, such as steep slopes. The designer should take account of Forestry Authority guidance for planning new woodlands within the landscape[82].

Nature conservation

10.17 Landfill restoration which includes tree planting will improve the nature conservation value of the site, by increasing the variety of wildlife habitats. The Forestry Authority gives practical guidance on developing nature conservation in new planting[83 84].

Amenity and recreation

10.18 Woodland close to urban centres provides amenity and recreational benefits. This is recognised in many areas through the creation of Community Forests. Many older landfill sites are located near towns, in areas identified in the local plan for amenity woodland, urban forestry or Community Forests.

10.19 The suitability of these sites for public access and enjoyment of new woodland depends on the criteria given in paragraph 10.11.

- On old sites where gas generation has ceased, the operator may allow public access; these schemes may be eligible for funding through the Woodland Grant Scheme[85].

- On modern sites public access should be postponed for safety reasons until gas generation has reduced.

The operator should fence around areas of new planting to protect the trees from grazing, disturbance and to reduce vandal damage. Forestry Authority publications provide information on planning and managing woodland for recreation[86 87].

[82] Forest Landscape Design Guidelines, Forestry Commission, 1994, HMSO.
[83] orest Nature Conservation Guidelines, Forestry Commission, 1990, HMSO.
[84] Creating New Native Woodlands, Rodwell, J. S. and Patterson, G. S., Forestry Commission Bulletin 112, 1994, HMSO.
[85] See Appendix H for more information on Woodland Grant Scheme.
[86] Forest Recreation Guidelines, Forestry Commission, 1992, HMSO.
[87] Community Woodland Design Guidelines, Forestry Commission, 1991, HMSO.

Timber production

10.20 Woodland may be established on landfills for commercial production, including

- timber products, including conventional sawlogs and small roundwood
- material for chipping or pulp
- coppice for energy production.

Suitable location, access and soil conditions must be provided.

10.21 The operator should consult the Forestry Authority on the potential of existing sites for commercial returns on planted woodland.

Requirements for tree establishment

10.22 The operator who intends to establish trees must consider

- landform and drainage: paragraphs 10.23 to 10.25
- soil requirements: paragraphs 10.26 to 10.33
- timing of tree planting: paragraphs 10.34 to 10.35
- cultivation: paragraphs 10.36 to 10.41.

Landform and drainage

10.23 Tree planting is most successful on a landform whose gradient encourages surface water drainage and thus minimises waterlogging: 1 in 10 should normally be the minimum gradient. Trees can however be established on shallower slopes where soils are reasonably freely-draining.

10.24 Tree planting can be carried out on steeper slopes than would be acceptable for agriculture. The maximum gradient for amenity planting is 1 in 3: steeper slopes cause difficulties in tree planting and management. The absolute limit for forestry equipment (downhill operation only) is 27° (approximately 1 in 2). On such steep slopes the operator must consider measures to reduce erosion, such as

- low maintenance grass sward
- cut-off berms every 20 to 30m.

10.25 Tree planting and woodland restoration schemes do not need underdrainage. Surface water drainage is by run-off and, on uncapped sites, drainage into the underlying fill.

Soil requirements

10.26 The main soil factors which determine the success of tree planting over landfills are

- adequate soil depth
- absence of compaction
- good drainage
- availability of topsoil.

i Soil depth

10.27 The Forestry Authority research (see paragraph 10.9) indicates the following minimum soil depths for tree growth:

- 1.0m over a synthetic cap
- 1.5m over a clay cap
- 1.0m over uncapped sites.

10.28 These conclusions are based on three essential requirements.

- Protection of the integrity of the cap.
- Provision of an adequate supply of moisture for tree growth.
- Provision of sufficient rooting depth to avoid windthrow.

10.29 Mature trees take up and transpire a substantial amount of water. The amount of moisture which trees require for satisfactory growth depends on climatic conditions and soil characteristics, mainly thickness, texture and stone content (see Chapter 8). The operator must provide an adequate depth of soil to meet transpiration requirements. The minimum recommended depths may need to be increased

- in especially dry parts of the country
- if the soil is coarse and stony (freely draining).

ii Absence of compaction

10.30 The recommended soil depths assume that tree rooting is not inhibited by compaction or waterlogging. Wherever practicable, soil should be loose tipped to avoid compaction: see paragraphs 8.59 to 8.70. Where loose tipping is not possible, or where soils re-consolidate after placement, compaction must be relieved by subsoil ripping: see paragraphs 8.83 to 8.89.

iii Good drainage

10.31 This is linked to absence of compaction and the looseness of the profile. Most trees, even those which tolerate waterlogging such as alders and willows, grow best in well drained soils.

iv Availability of topsoil

10.32 Topsoil is not essential for establishing trees for amenity planting. Amenity planting may be a suitable after-use where the lack of topsoil limits agricultural restoration. Topsoil encourages vigorous grass and weed growth which reduce the availability of moisture and light to the establishing trees.

- If trees are planted into topsoil, regular weed control must be carried out around each tree for good tree establishment and growth.

If topsoil availability is limited, the operator should consider a combination of agriculture and amenity woodland, and use the topsoil on agricultural areas.

10.33 Woodlands which are planted for commercial cropping, however, need topsoil if they are to be adequately productive.

Timing of tree planting

10.34 On a landfill site that is still settling, the engineering systems are likely to need remedial works for some years after completion of landfilling. On such sites the operator should **delay** tree planting until after the period of most active settlement. On most sites there will be opportunities for early tree planting for screening and landscape enhancement

- ► around the perimeter of the site
- ► on areas which have not been landfilled.

Hence

- the operator should discuss a *staged approach* to tree planting with the LPA.

10.35 If early tree planting is necessary, the landscape designer and the gas engineers must agree tree planting proposals on areas of gas extraction and control. The landfill designer must

- ► leave space for access to pipelines and wells for monitoring and maintenance
- ► leave sufficient working area around wellheads.

On sites which are relatively shallow, or filled with a large proportion of inert materials, settlement should not cause delays to tree planting.

Cultivation

10.36 Restored soils are normally in a suitable condition for tree planting because of initial loose tipping or subsequent subsoil ripping. A final cultivation with heavy discs or a mould-board plough may be useful to work materials such as sewage sludge into the soil.

10.37 The operator should establish a **grass sward** on tree areas before planting

- on highly visible areas to improve the appearance of the site
- over a capped site to reduce rainwater infiltration
- on gradients to control erosion
- where herbaceous weeds must be controlled
- where nature conservation objectives are to introduce wild flowers into planted areas.

10.38 Grass establishment requires the cultivation and seeding techniques described in Chapters 8 and 11. The ground cover should not be so vigorous that it competes with the trees for moisture, light, space and nutrients. Typical ground cover vegetation includes

- *grass mixtures* - non-competitive and low seed rates reduce competition with the trees: mixtures of fescues and legumes are recommended
- *legumes* - these fix nitrogen if sown with inoculants; Table 10.1 lists suitable species.

10.39 Clovers can compete with establishing trees and shrubs: a mixture of less aggressive clovers and smaller legumes (*Medicago, Lotus*) may be more appropriate. Legumes do not tolerate dense shade, and gradually recede as the canopy cover increases. Soil structure will have improved sufficiently to make them unnecessary by this time.

10.40 If soils have not been loose tipped, or tree areas have a grass cover, the planting area should be subsoil ripped along the planting lines to a depth of 300 - 450 mm before planting. This **pre-planting rip**

- loosens the soil along the planting lines
- encourages infiltration of moisture and nutrients down to the tree roots
- enables the contractor to achieve better standards of planting.

10.41 Fertilisers are applied

- by tractor mounted mechanical spreader before planting
- manually round each tree during the first 1 to 5 years after planting.

If the operator or his contractors intend to use sewage sludge in tree areas, this must be carried out in accordance with the regulations[88] and published advice[89]. Sewage sludge supplies nutrients and organic matter, but should be analysed for heavy metal content: see Chapter 8.

Table 10.1 Ground cover legumes for tree planting

Species	Lifespan	Soil pH range	Nutrient demand	Tolerance of	
				Drought	Waterlogging
Tree lupin (*Lupinus arboreus*)	short-lived	4.5 - 7.0	L	T	MT
Everlasting pea (*Lathyrus sylvestris. L.latifolius*)	perennial	4.0 - 7.5	L	T	MT
White clover (*Trifolium repens*)	perennial	5.5 - 7.0	VH	S	MT
Red clover (*Trifolium pratense*)	biennial	5.0 - 7.5	VH	MT	S
Birdsfoot trefoil (*Lotus corniculatus*)	perennial	4.5 - 8.0	M	T	MT
Sainfoin (*Onobrychis viciifolia*)	short-lived	6.5 - 8.0	M	T	T
Lotus `maku' (*Lotus uliginosus*)	perennial	4.0 - 7.0	M	MT	T
Lucerne (*Medicago sativa*)	perennial	5.5 - 8.0	VH	T	S

L: low; M: moderate; VH: very high; S: sensitive; MT: moderately tolerant;
T: tolerant

[88] Sludge (Use in Agriculture) Regulations 1989.
[89] Manual of Good Practice for the Use of Sewage Sludge in Forestry, Wolstenholme, R, et al., Forestry Commission Bulletin 107, 1992, HMSO.

Choice of species, planting and establishment

Choice of tree species

10.42 The choice of species is influenced by site conditions, intended after-use and local vegetation patterns. Site conditions which influence species choice include

- drainage
- soil pH
- topsoil availability
- pollution level (including landfill gas)
- local climate
- exposure.

The choice of tree species should also reflect the objectives of the tree planting, whether wholly or partly for commercial, wildlife, amenity or recreational needs. Indigenous species are most suitable for amenity or nature conservation planting, but more productive species should be chosen for timber or energy cropping.

10.43 Choice of tree species must depend on its tolerance of conditions on landfill sites: see Table 10.2. Common indigenous tree species are generally tolerant of variable soil conditions, although species have individual preferences and requirements. Beech and hornbeam frequently do not tolerate conditions on man-made sites, birch is not appropriate for sites with a high pH, and ash will not thrive on soils with a low pH.

Table 10.2 Trees most likely to tolerate conditions on landfill sites

species	heavy soils	calcareous soils	acidic soils	exposure	air pollution	Comments
Broadleaves						
Ash	x	••	x	x	x	More fertile sites only
Common alder	••	•	•	•	••	Nitrogen-fixing
Crack willow	••	••	x	x	•	
Downy birch	•	•	•	••	••	Tolerates low fertility
English oak	•	•	•	•	•	More fertile sites only
False acacia	•	•	••	x	••	Nitrogen-fixing.South only
Field maple	•	••	•	•	•	
Goat willow	•	•	•	x	••	
Grey alder	••	•	•	•	•	Nitrogen-fixing
Grey poplar	••	••	•	••	••	
Hawthorn	•	•	•	••	•	Tolerates browsing
Italian alder	•	••	x	x	••	Nitrogen-fixing
Norway maple	•	••	x	••	•	
Red alder	••	x	•	••	•	Nitrogen-fixing
Red oak	•	•	••	•	•	
Rowan	•	•	•	••	•	
Silver birch	x	x	••	•	••	Tolerates low fertility
Swedish whitebeam	••	•	•	•	•	
Sycamore	•	••	•	•	••	
Turkey oak	••	•	•	x	•	
Whitebeam	•	••	••		•	
White poplar	••	x	•		••	
Wild cherry	x	•	x		•	More fertile sites only
Conifers						
Corsican pine	•	••	••	••	••	Below 250 m O.D.
European larch	•	x	•	•	x	
Japanese larch	•	x	•	•	•	
Leyland cypress	•	•	•	••	••	Mainly for shelter
Lodgepole pine	•	x	••	•	x	North only
Scots pine	x	x	••	••	x	

Species are classified as tolerant (••), moderately tolerant (•), or intolerant (x)

10.44 A survey of 19 landfills carried out in 1991 suggested that alder, birch, wild cherry, English oak, sessile oak, Turkey oak, field maple, Norway maple, sycamore and willow all grow successfully on landfill sites. Several indigenous shrubs may also be planted with trees or at the edge of tree areas to encourage wildlife. These include hawthorn, blackthorn, elderberry, guelder rose, bramble and shrubby willows.

10.45 In most situations mixtures of species are more attractive than pure stands and are ecologically more diverse. Alders are particularly useful components of such mixtures because they fix nitrogen like clovers. In many locations faster-growing, more tolerant species, such as alder and birch, should be planted as nurse species to shelter and encourage the growth of slower growing, long term species, like oak, maple and ash.

Planting stock and quality assurance

10.46 Restored sites are normally planted with nursery-raised stock. Direct tree seeding (sowing tree seed directly into the ground) cannot yet be recommended. Large trees are more difficult to establish, especially on

- sites which are exposed to strong or drying winds
- sites where topsoil is not available
- sites which are vulnerable to vandalism.

Very small plants are susceptible to frost heave and weed competition.

10.47 The most useful stock types are

- *transplants* - small trees less than 1.2m tall and up to 3 or 4 years old; categorised according to the number of years spent in the nursery as seedlings and after transplanting in the nursery: 1+1, 2+1
- *undercuts* - the same size and age as transplants; grown as seedlings, then undercut without moving to sever side and downward growing roots; categorised as transplants: 1u2
- *container grown* - obtainable in a range of sizes, ages and types, generally more expensive than transplants or undercuts; the main benefit in using these is minimal root disturbance at planting.

10.48 Stock should always be obtained from a reputable nursery, preferably a member of the Horticultural Trades Association. The stock should be healthy and free of obvious pests and diseases. The plant should have a well-developed fibrous root system, and should generally not be more than 600 mm in height.

10.49 It is essential to minimise the delay between lifting the trees in the nursery and planting on site. During that time the roots must be kept covered to protect them from drying out and from frost.

Planting and establishment

10.50 Planting and subsequent maintenance must be carried out by competent and experienced staff.

10.51 For transplants and undercuts notch planting with a spade is generally the best method (see Figure 10.2). However, pit planting is better on clayey soils, and for container grown plants. In pit planting, a pit is dug and the tree is put into it. The soil is replaced and firmed around the plant as in notch planting.

10.52 Trees are usually planted in rows at regular spacings, typically 2m apart to give a planting density of 2500 plants per hectare. Where pre-planting ripping is carried out, the tree should be planted in the disturbed soil at the side of the rip line.

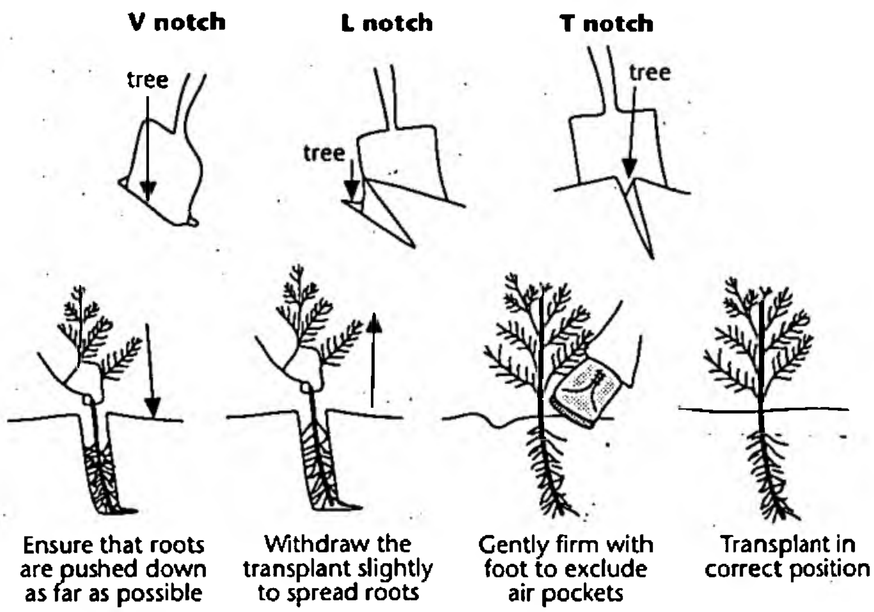
10.53 Trees should be planted when they are dormant, usually between late autumn and early spring (before the end of March) but preferably not in midwinter.

10.54 Trees benefit from annual fertiliser dressings, applied around the tree and not to the general area, especially if the substrate is generally of low fertility. To be effective, fertiliser applications must be combined with herbicides to control grass and weed growth round each tree.

- An area of 1 m diameter around the tree should be kept clear of weed growth.

10.55 Applications of propyzamide (in winter) or glyphosate (at any time of year), are suitable herbicide treatment for tree areas. The choice and application of pesticides is controlled by legislation[90]. Operators should check that their maintenance contactors are aware of this legislation.

Figure 10.2 Planting methods



10.56 Weeds can also be controlled by mulching with black polythene mats.

10.57 Young trees should also be protected from damage by small and large mammals, including rabbits, voles, deer and farm stock. There are a number of proprietary individual tree guards, for smaller areas. Large areas (more than 2 hectares) may be protected by suitable post and wire fencing. Keeping a clear area around each tree will reduce damage by voles.

10.58 Some losses after planting should be expected on most sites due to poor stock, poor planting technique, mammal, insect or fungal attack or drought. After the first season planted areas should be regularly inspected, and dead and dying plants replaced: this is known as beat-up. The causes of death or damage should be investigated and remedial action taken.

[90] The Control of Pesticides Regulations 1986.

Chapter 11

Restoration and aftercare for amenity and nature conservation

Introduction

11.1 This chapter describes the techniques used to restore all or part of a landfill site for amenity and nature conservation after-uses. The chapter is divided into

- opportunities for amenity and nature conservation after-uses: paragraphs 11.3 to 11.20
- specification for open space, formal recreation and nature conservation: paragraphs 11.21 to 11.31
- choice of vegetation and seed mixtures: paragraphs 11.32 to 11.40
- habitat creation techniques: paragraphs 11.41 to 11.52.

11.2 The chapter concludes with a section on nature conservation and public access. Sources of information and advice are given in Appendix J.

Opportunities for restoration for amenity and nature conservation

Amenity

11.3 Land is restored for amenity for the following uses:

- open space used for informal recreation - country park, golf course, horse riding, cycleways and footpaths
- formal sports facilities - sports pitches, athletics tracks.

i Open space

11.4 The operator should consult the local authority leisure and conservation departments to identify local needs for formal and casual recreation and for nature conservation (see also Chapter 4).

11.5 Landfill sites near residential areas are often more appropriate for amenity and casual recreation than for agriculture or woodland. Within towns, sites filled with excavation and construction wastes provide this opportunity. Old unrestored landfills, surrounded by housing and awaiting restoration, are also suitable for amenity after-uses.

11.6 Restoration for amenity creates areas of open space where casual recreation pursuits may take place, combined with areas of nature conservation or wildlife interest. The site may become

- public open space (POS) or a country park which is maintained by the local authority for public access and enjoyment

- an area of casual recreation with public access, but which is privately maintained for purposes such as golf courses and sports pitches.

For ease of reference both are referred to in this Chapter as open space. These sites may vary in size from very small (less than 1 hectare) to large (more than 20 hectares).

11.7 This after-use commonly has areas of maintained grass sward, with structure planting of trees and shrubs for visual interest and shelter. In addition to any definitive public footpaths, other means of public access must be carefully considered:

- the site may be fenced with specific points of access, or unfenced for unrestricted public access

- footpaths routes are important if the site is to be popular with local residents; hard surfaced paths constructed of gravel, ash or rolled stone should follow obvious desire lines across the site, other paths will develop with use

- cycleways and bridlepaths may be needed in some areas

- planted areas should be fenced to prevent general access for at least the first 5 years to allow trees and shrubs to establish.

11.8 In urban locations, sites intended for amenity after-uses are likely to have been used for activities such as motorcycling, fly tipping, and occupation by travellers. Sites which have been unused for some time may have a history of such mis-use which will be hard to overcome. The site should be securely fenced and site boundaries and entrances must be maintained for successful restoration.

ii Formal sports and recreation

11.9 The operator should consult the local authority and local plan if he intends to restore a site to provide facilities such as golf courses and driving ranges, or more uncommon facilities such as dry ski slopes. He may also wish to consult specialist consultants for further advice on design, construction and commercial aspects.

11.10 The need for sports facilities, such as playing fields, athletics tracks, cycle and motorcycle tracks, is most likely to be promoted by the local authority, and specialist advice should be sought for their design and construction.

Nature conservation

11.11 The factors which the operator should take into account when considering restoration for nature conservation are detailed in Chapter 4. Wherever possible, nature conservation should complement any local authority initiatives included in the development plan or nature conservation strategy, so as to contribute to an overall provision for wildlife.

i Species-rich grassland

11.12 Species-rich grassland, or wild flower meadows, are an appropriate alternative to agriculture in many situations.

11.13 Small sites, especially in urban areas, are suitable for restoration to a species-rich grassland. These sites are usually unsuitable for restoration to agriculture because

- they may have been derelict before landfilling and lack on-site soils: soil importation will bring heavy goods vehicles onto narrow, unsuitable residential streets; nature conservation may require less soil for restoration

- such sites may have been neglected for years allowing an interesting flora to develop which is greatly appreciated by local residents: restoration to a formal after-use may be inappropriate, the restoration strategy should preserve existing vegetation where possible.

11.14 Species-rich grassland provides an attractive appearance to the restored site and brings wildlife interest into urban and residential areas, thus benefiting the urban environment in both visual and wildlife terms. The site may become a wildlife habitat or wildlife corridor, adding to the existing mosaic of sites in the area.

11.15 Species-rich grassland should also be established

- on amenity and open space sites

- in clearings and open spaces within woodland

- in small areas on agricultural sites which cannot be economically farmed.

Species-rich grassland requires little maintenance, but should be cut for hay once or twice a year. The hay may be sold for fodder or animal bedding.

11.16 The low maintenance requirements of species-rich grassland make it a more suitable after-use than agriculture for sites with frequent gas or leachate manholes. In an arable field, the working areas round the manholes affect the viability of commercial cropping: see paragraphs 9.7 to 9.15. In a wild flower meadow they matter much less.

ii Heathland

11.17 Redundant stone quarries are often restored by landfill, and these may be located in upland or moorland locations where restoration to agriculture or woodland would be inappropriate.

- Such sites are frequently in areas of great natural beauty where the main objective of restoration is to integrate the site into its surroundings.

This is most effectively achieved by establishing the original local vegetation type, such as fescue grassland, heather, and occasional trees and shrubs such as oak, birch, mountain ash (rowan), gorse and bilberry.

iii Ponds and wetlands

11.18 Water features greatly increase the site's visual and wildlife interest, but the opportunities for creating ponds and wetland habitats on landfill will depend upon

- the nature of the fill
- site specific characteristics.

Creating ponds over the cap may increase the risk of water infiltration through the cap and into the waste thus increasing leachate volumes, and should generally be avoided.

11.19 Ponds and wetlands can sometimes be constructed without undue risk to pollution control systems. These opportunities occur

- at sites which have accepted only inert wastes
- at the edges of sites, outside the landfilled area.

11.20 The operator may consider combining the function of ponds at the edge of the site for both nature conservation and surface water retention. This is important in landraising schemes where a substantial capacity may be required to hold surface water run-off and release it at a controlled rate into local watercourses. Retention ponds may also be planted with reed beds to improve the quality of the water before it is discharged to stream. Such ponds may be large enough to be used for fishing as well as nature conservation.

Table 11.1 Recommended minimum soil depths for amenity and nature conservation

After-use	Subsoil	Topsoil
Intensively managed amenity grass sward	1m over capped site 500mm over inert wastes site	150mm over capped and inert wastes sites
Sports pitch	1m over capped and inert wastes sites	150mm over capped and inert wastes sites
Low maintenance amenity sward	1m over capped site 500 mm over inert waste site	Not essential
Woodland	1.5m over clay capped site 1m over inert wastes site or synthetic cap	Not required
Species rich grassland	1m over capped site 500mm over inert wastes site	Should not be used
Heathland	1m over capped site 500mm over inert wastes site	Use any locally occurring soils but do not import topsoil

Specification for amenity and nature conservation after-uses

11.21 This section describes the requirements for each amenity and nature conservation after-use:

- open space
- formal recreation
- nature conservation areas.

Open space

11.22 The contours for open space must be safe for cultivation and grass maintenance, but are otherwise variable to suit the site and its surroundings. Recommended gradients for aftercare activities are given in Chapter 6, Table 6.1.

11.23 The gradients for amenity and casual recreation should encourage natural drainage. Variable gradients, giving an interesting final landform, should be used to screen the gas and leachate treatment compound and ancillary facilities without being obtrusive.

11.24 The soil requirements for amenity and casual recreation, see Table 11.1, will depend on

- the objectives of the design
- the degree of wear caused by the after-use.

Grassland areas which are frequently used should be restored with topsoil to promote strong grass growth. For after-uses such as licensed motorcycle scrambling and cycle tracks, increased soil depths and the use of geotextiles may be necessary to protect the cap.

Formal recreation

11.25 Formal sports pitches have very specific requirements for gradients and drainage. Gradients are generally shallow or flat and are therefore sensitive to even slight differential settlement. If the operator intends to locate sports pitches over landfill which is expected to settle, he should undertake interim restoration (see paragraphs 7.18 to 7.25). This should enable imperfections in the gradient to be corrected before final soil replacement and drainage.

11.26 The requirements of the gas control system may also be incompatible with formal recreation. Unless the control system is designed to avoid locating surface features on the pitch areas, problems will occur for

- access for monitoring and maintenance
- pitch maintenance.

11.27 The designer should seek specialist advice on soil types and the design and installation of underpitch drainage systems.

11.28 The operator and the designer must carefully consider the siting of any buildings associated with the after-use, such as pavilions and changing facilities, particularly on sites which may generate gas. Precautions must be taken to prevent the build up of gases which are potentially explosive, flammable or asphyxiating in confined spaces: see Chapter 12. Structures must be located on a part of the site which has not been filled or on adjacent land.

Nature conservation areas

11.29 There are no special gradient requirements for restoration to nature conservation after-uses. Slopes should promote natural drainage unless waterlogging, wetlands and ponds are being specifically created. These after-uses are not sensitive to problems associated with waterlogging due to settlement because wetter areas will provide different wildlife habitats.

11.30 The principal soil requirement is low fertility which increases the variety of wild flower species. This in turn attracts birds and especially insects. Topsoil encourages coarse grasses and invasive perennial weeds. Successful wildlife habitat restoration schemes may be developed using

- very poor subsoils
- soil with a high stone content
- quarry wastes and clay soils.

The choice depends upon the type of habitat which is to be created. Table 11.1 gives recommended soil depths.

11.31 If the site is in or near areas of wildlife interest, local sources of soil should be used wherever possible, especially for upland or heathland restoration. The local soils may contain seeds of locally-occurring plant species which make the restored site blend into its surroundings

Choice of vegetation and seed mixtures

11.32 The choice of vegetation and seed mixtures is influenced by site conditions and the required after-use. This section offers advice on the choice of vegetation for

- amenity and formal recreation
- species rich grassland
- heathland.

Amenity and formal recreation

11.33 A range of amenity grass seed mixtures are commercially available to suit most soil types and situations. Some are hard wearing to withstand intensive use, others are low-maintenance mixtures which are more suitable for areas which will not be regularly used. Advice should be sought from specialist seed houses on mixtures suitable for sports pitches and out fields.[91]

[91] Advice on sports grass seed varieties may be obtained from Sports Turf Research Institute, Bingley, W. Yorkshire, BD16 1AU.

Species-rich grassland

11.34 Seed mixtures for species-rich grassland, or wild flower meadows, are available from many seed houses and specialist firms. These are generally designed for different soil types and shade conditions. Wild flower seeds are usually combined with suitable grass varieties, and the seeding rate is also specified. Some specialist firms supply seed of individual flower species, to enable the species mix to be specially selected for the site: this will be useful if the objective is to establish the same species on site as in the surrounding land.

11.35 Locally-collected seed may also be available which has the advantage of supplying local plant types. This may be ecologically important where local ecotypes need to be preserved. This seed may not comply with the high standards of quality in terms of purity and viability which may be expected from commercial seed houses of good reputation.

11.36 All wild flower seed has specific requirements to trigger germination, and it may take several years for some species to germinate.

11.37 Species rich grassland may also be established by cutting the seeding grass and plants (as though taking a hay crop) in an area of grassland which is to be used as a donor site, and spreading the cut grass onto the receptor site. This technique relies on the *direct transfer* of cut grass and flower heads to the receptor site, as storage of the hay leads to a rapid deterioration in seed viability. The hay is spread on the prepared area, and raked up and collected for disposal after about a week, by which time the seed will have dropped onto the soil. This technique will produce an ecological replica of the donor site, given similar conditions of aspect and soil: this may be important if the source is a site of ecological significance which is to be extended elsewhere[92].

11.38 Individual plants may be introduced during the same season as sowing, or subsequently. These may be native trees and shrubs (see Chapter 10), or herbaceous species purchased in containers or moved from other sites.

11.39 Wild flower seed need not always be included with the grass seed, particularly in tree and shrub areas. As long as there is a seed source close to the site, a wide variety of species will seed naturally into grassland areas, especially where

- the grass is not growing too vigorously
- no herbicide treatment is being carried out.

Heathland

11.40 Heather can be established on new areas by seed transfer from cut vegetation. The heather plants are cut with a forage harvester after flowering, and the cut vegetation is spread directly onto the receptor site as a mulch. Expert advice should be sought as to the best source of heather and the optimum time for cutting.

[92] The Use of Hay Strewing to Create Species Rich Grasslands, Grant H Jones, Ian C Trueman, Peter Millet, British Ecological Society Conference, Leicester, March 1995, published in Land Contamination and Reclamation Vol. 3, No. 2, 1995.

Habitat creation techniques

11.41 These techniques are aimed specifically at creating particular target habitats. All habitats are, to some extent, transitory and subject to change. The most interesting habitats are often those which are uncommon such as wetlands and damp meadows, and these are infrequent because they are very susceptible to change. Because habitats are not static, creating a specific habitat requires management to arrest the processes of nature: see Chapter 13.

11.42 The conditions of soil, water regime, shelter and shade are important to create the right environment for particular plant communities. These will act as host and food plants to insects and other fauna, so that other typical species will colonise naturally.

Species-rich grassland

11.43 The techniques for establishing this habitat from seed are described in paragraphs 11.34 to 11.39. Grassland can also be established by translocating large turfs *(turf transplanting)*. Turf cutting buckets, purpose-built to be attached to tracked excavators, are designed to take turfs up to 2 square metres in size, dug to a depth of 150 to 250 mm.

11.44 Turf transplanting is most successful on short grassland, such as chalk downland: the grass roots hold the turf together and enable it to be moved to the receptor site without breaking up. This technique has the advantage of moving the whole plant community relatively intact. It is relatively expensive, and usually used only where an ecologically important area is to be lost.

Woodland

11.45 The woodland plant community develops by gradual succession over many years. The ground flora establishes because the seasonal conditions of light and shade intensity favours it. Without the mature tree canopy overhead, it would not survive the invasion of more aggressive species no longer suppressed by the shade. To establish a true woodland habitat, one must not only plant trees but also promote shady conditions to encourage the woodland flora to gradually develop.

11.46 On landfills, a mixed scrubby woodland with shrub species, particularly around the edge of mass planted areas, can be established within 10 to 15 years. These areas provide a habitat for small mammals and birds. Sheltered clearings within the woodland area also encourage invertebrates, especially butterflies and moths.

Heathland

11.47 It is essential to create the correct soil conditions for successful heathland restoration. If soil is available from the original site or a nearby source this is most likely to be suitable, and may contain seed and plants which will rapidly establish an authentic plant community. A technique for establishing heather from seed is described in paragraph 11.40. Heather can also be established using commercially available seed and young plants.

11.48 It is advantageous to establish a grass sward using species such as fescue and bent

- to stabilise bare ground
- to suppress more competitive weed species
- to create a suitable micro-climate for heather germination.

It is essential to protect the germinating seedlings from rabbit grazing.

Ponds and wetlands

11.49 The normal way of forming a pond is to excavate a pit and line it with clay or an impermeable membrane. In many landfill situations it is not desirable to excavate into underlying materials and the pond can be formed by building up embankments around the pond and lining the depression thus formed.

11.50 The pond sides should be gradually shelving to give areas of shallow water and damp conditions where water margin plants such as reeds, rushes, sedges and iris can establish. Shelving banks also allow access to the water for birds and animals: see Figure 11.1.

11.51 Ponds need not be large for wildlife interest. Birds, insects, amphibia and small mammals will be attracted to

- a small pond, 10 to 20 metres diameter, surrounded by seasonally flooded wetlands
- a series of small ponds, formed by widening an existing or new watercourse by 2 to 3 metres, linked by wetland areas.

A small island in the pond increases its attractiveness to wildlife. The island need not be more than a few metres across if space is restricted. A wildlife pond should not be deep: 600 mm to 1 metre depth of water is sufficient to prevent drying out in the summer.

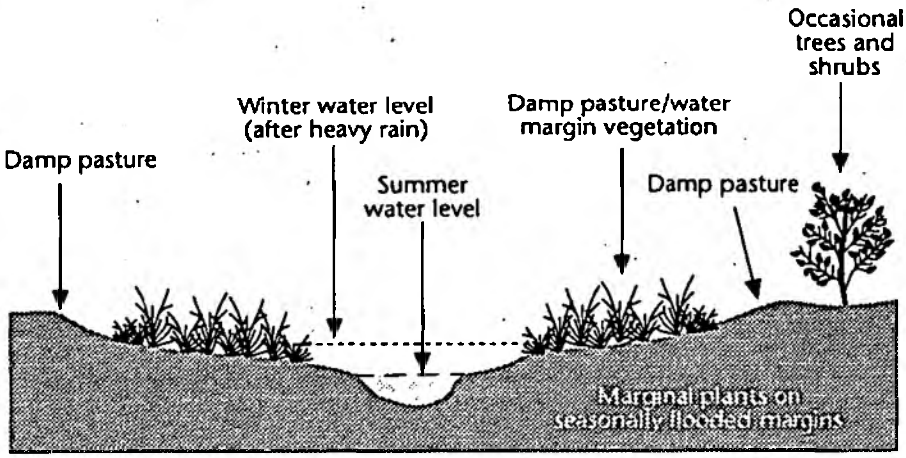
11.52 If the pond is to act as a retention pond for surface water run-off, its size and capacity must be calculated from predicted run-off volumes. The water should enter the pond through a small settlement lagoon or silt trap to remove sediment.

- If surface water could become contaminated with leachate, water quality should be sampled and monitored before it enters the pond.

Alternative disposal arrangements for contaminated run-off may be necessary. The pond should also have an exit sluice to control the rate of discharge. This may be designed

- to maintain water in the pond at all times
- to give seasonal water areas.

Figure 11.1 Stream edges managed for wildlife



Other considerations

Nature conservation and public access

11.53 An important objective of many nature conservation schemes is public enjoyment, yet public access may damage a sensitive habitat. Members of the public should be encouraged to follow paths and boardwalks to areas which will tolerate disturbance. The operator can protect sensitive areas by

- making access difficult
- locating such areas at some distance from the main entrance.

Public access to the leachate treatment and landfill gas control compounds must be prohibited for site safety.

11.54 The operator, or landowner, may wish to consider an access agreement with the local authority making the restored land available for public access either generally or along specific paths[93]. Nature conservation areas may be designated as local nature reserves with the approval of English Nature; public access must be provided.

11.55 The operator may wish to provide car parking facilities, a visitor centre, information boards about the site and the like. Information boards serve the dual purpose of

- providing information about the site
- explaining the restoration scheme

thus benefiting the operator's reputation.

[93] National Parks and Access to the Countryside Act 1949.

11.56 At a nature conservation site, the car park and other public access areas must be carefully sited away from bird breeding areas and other sensitive habitats. The designer should consider partially screening car parking and the entrance area from the rest of the site.

11.57 If the nature conservation area is not on operational parts of the site, the operator may wish to consider opening it as a local educational resource while the site is still operational. The entrance to the nature conservation area must be separate from the operational site entrance, to minimise conflicts between site traffic and visitors.

Chapter 12

Restoration for hard end uses

Introduction

12.1 This chapter is an outline guide to the relevant considerations for landfill restoration for hard end uses, including the construction of hard standing areas, built development and structures. The chapter describes

- the principal hazards
- general construction principles and methods for minimising the risks from such hazards.

12.2 The operator or developer *must* be aware of the risks and consequent costs of built development on landfills, and the fact that, apart from exceptional circumstances, this form of after-use is not advised.

12.3 If the operator intends to construct buildings on the site he is strongly advised to seek appropriate specialist advice from the Building Research Establishment and the British Standards Institute.

12.4 The chapter is also relevant to other hard end uses of landfill sites, which may include car parks, lorry and container parks, small industrial and commercial units. It describes the key design areas, particularly with reference to landfill gas migration and control and settlement.

12.5 The matters addressed in this chapter are also relevant to sites with a mixed after-use which includes structures and areas of vehicle access, loading and parking.

Principal constraints to hard end use development

12.6 The principal hazards associated with the use of former landfills for construction and hard end uses are

- the presence of biodegradable materials which release flammable and explosive gases as they decay
- geotechnical conditions which may be unsuitable for the construction of buildings due to instability and settlement
- toxic substances or chemicals in the fill which may attack building materials.

12.7 The Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL)[94 95] publishes guidance on the problems of redeveloping landfill sites. The operator should follow this guidance unless he has strong technical advice to the contrary.

[94] Notes on the Development and After-Use of Landfill Sites, ICRCL Guidance Note 17/78, 1990.
[95] Guidance on the Assessment and Redevelopment of Contaminated Land, ICRCL Guidance Note 59/83 (2nd Edition) 1987.

12.8 Because of the factors listed in paragraph 12.6, landfills are generally considered to be unsuitable for hard forms of development (buildings or structures) unless appropriate remedial treatment is carried out prior to construction. This is likely to be complex and expensive.

- Houses should generally **not** be built on a site that generates landfill gas. Such development would require stringent precautions such as
  - sub-floor cavity ventilation
  - gas detectors and alarms.

12.9 These precautions must be extended to include extensions, garden structures such as greenhouses, conservatories and sheds. Activities such as bonfires and barbecues must be restricted.

Choice of form of development

12.10 The most suitable form of development cannot be decided until site investigations have been undertaken[96]. It is the developer's responsibility to satisfy himself that the site is safe and suitable for the proposed development.

This will involve a thorough investigation to assess the significance of the hazards on the site, in particular

- land contamination
- presence of flammable and toxic gases
- ground stability (both long and short term).

The operator should seek specialist advice to ensure that the investigation is sufficiently detailed to enable the choice and design of the development to proceed. He should also refer to the relevant published guidance[97].

12.11 If the site has taken only inert wastes, the operator has a wider choice of hard end uses than at a biodegradable site. Inert waste sites have significantly less potential for settlement and landfill gas generation, and the fill is less likely to contain substances that affect construction materials. The cost of construction on inert waste sites is less than on landfills which have taken biodegradable wastes. Safety precautions may also be significantly reduced.

Building control

12.12 The operator must take precautions to avoid risks to health caused by substances in ground to be covered by a building[98]. Appropriate action includes

- removing contaminants

[96] Code of Practice for Ground Engineering Investigations, BS 5930, British Standards Institution.
[97] PPG14 Development on Unstable Ground.
[98] The Building Regulations 1985 (Schedule 1 Part C) Approved Document C.

- limited excavation, filling and sealing
- sealing service entries
- eliminating voids
- sealing or effectively ventilating voids which cannot be eliminated.

He should also take appropriate action to deal with contamination, including leachate and gases, on other parts of the site that are not to be covered by buildings.

12.13 The design specification for buildings on former landfill sites may include

- special piled or suspended slab foundations to
    - minimise settlement problems
    - prevent methane migration
    - reduce the extent of excavation into waste, which itself has health and safety implications
- raising the building clear of the ground to create a space beneath the building which may be ventilated: a ventilation scheme must be subjected to quality assured management
- artificial gas proof barriers, monitoring points and automatic alarms for methane and carbon dioxide within the building cavity or service ducts.

These features are more suited to industrial units, offices and commercial developments than to private houses.

Potential hazards

Landfill gas

12.14 The presence of landfill gas is a material planning consideration which the developer must take into account in any proposal to redevelop sites on or near landfill sites. Table 12.1 relates development possibilities to gas emission profiles. Government guidance[99] [100] advises local authorities

- should exercise due caution in granting permission for development on landfill sites
- should refrain from granting permission unless reliable arrangements can be made to overcome the danger of migrating gas.

[99] Development of Contaminated Land, DOE Circular 21/87 (W.O. 22/87), DOE and Welsh Office, 1987, HMSO.
[100] Landfill Sites - Development Control, DOE Circular 17/87 (W.O. 38/89), DOE and Welsh Office, 1989, HMSO.

Table 12.1 Development possibilities relative to gas emission profile

Gas emission profile	Examples of sites	Development possibilities
Gas produced continuously, usually released at low rates. Concentrations of flammable constituents may exceed lower explosive limit (LEL) values.	Older landfills containing minor amounts of biodegradable matter.	Building development may be possible with passive protection systems and suitable design allowances (e.g. ventilation of structure and elimination of voids where possible).
Gas emitted rapidly in large volumes under pressure, causing vertical and lateral movement. Methane often present at high concentrations together with other gases which may modify its behaviour e.g. CO_2.	Landfill sites containing a high proportion of biodegradable material e.g. household waste.	Housing development is to be wholly avoided. Other forms of hard development are best avoided until emission ceases. If such development must unavoidably proceed, i) carry out thorough investigation; ii) design active protection systems e.g. gas collection/extraction wells, gas detectors and alarm systems; iii) monitor effectiveness of precautions before, during and after development.

12.15 The potential dangers of landfill gas are mostly associated with the asphyxiating and explosive properties of methane. Landfill gas also contains high proportions of carbon dioxide which is an asphyxiant at concentrations exceeding 1.5%.

12.16 If the operator intends to restore a site to a hard end use which is producing or has the potential to produce gas, active extraction and alarm systems must be installed. These must be designed to prevent the build-up of gases within structures or below the paving or hard surface of the site. Continuous gas monitoring will also be essential.

12.17 If gases are allowed to build up beneath the site they may migrate sideways, or be forced up through gaps in the surfacing, causing a hazard. The design and installation of gas control systems are described in WMP26B; these are not specifically applicable to the protection of buildings.

12.18 Passive gas venting columns cannot be relied upon to provide adequate gas extraction, unless methane levels are extremely low: even then they may be ineffective in certain weather and atmospheric conditions, and unsafe in areas of frequent public access.

12.19 A porous layer beneath the hard surfacing, which may be ventilated by injecting clean or inert gases to force methane into a collection system, will provide added protection.

12.20 The Building Research Establishment[101] have prepared advice and guidance on building design and construction techniques which include the following.

- Designing foundations to avoid the possibility of unventilated spaces within or beneath the building.
- Providing gas traps or other special precautions at the points of entry of essential building services, especially water supplies, drains and electricity cables.
- Providing adequate internal ventilation for both below ground and above ground parts of the buildings, with monitors and alarms to respond to a build-up of hazardous gases.

12.21 The operator should seek the professional advice of structural engineers, foundation design specialists and ventilation experts during the design process.

12.22 Remedial measures must be

- **durable** - that is, effective for as long as they need to be
- **robust** - that is, practical and not over-dependent on close control of design features.

The operator is responsible for the safe development and secure occupancy of the site.

12.23 Active gas extraction requires either a flare stack or gas utilisation facility. On an industrial development, the gas compound and flare stack may be in keeping with the setting; but even here the design of the flare and secure screen fencing should be carefully considered.

12.24 The integrity of safety precautions within occupied buildings may depend on the continued operation of the gas extraction system. If so, security and the prevention of vandalism will be paramount. The operator may decide to employ a specialist security firm for continuous surveillance.

Site stability and settlement

12.25 Structural precautions will depend on

- ► the type of waste fill
- ► the rate of waste input
- ► the method of operation.

[101] More information on building and construction techniques may be obtained from Building Research Establishment, Garston, Watford WD2 7JR (Tel: 01923 894040).

The British Standard Code of Practice for Foundations (CP2004) warns that *all made ground should be treated as suspect, because of the likelihood of extreme variability.*

- A geotechnical investigation of the site should be undertaken prior to the design of foundations or other structures.

Protection of associated landscaped areas

12.26 The design of the development may include planted beds or other such landscaping around buildings or dividing car park areas. The planting areas must be isolated from the fill by

- ► a conventional cap over the landfill, or
- ► individual containment membranes under each planting area.

It is essential to ensure that lateral migration of gas beneath the surface of the development does not vent to atmosphere through the soil in planted areas. If each planting area is to be separately contained, they must be drained so that they do not become waterlogged during heavy rain.

Chapter 13

Vegetation establishment and maintenance

Introduction

13.1 This chapter provides guidance on the techniques used to establish and maintain vegetation on restored sites. The works described in this chapter are undertaken during the aftercare period (as defined by the planning permission), and will continue for as long as necessary throughout the post-closure period.

13.2 The operator is responsible for the works during the aftercare period, and may choose to retain some responsibility beyond this in view of his continuing responsibility for pollution control.

13.3 The chapter is subdivided into sections giving guidance for different after-uses as follows:

- agriculture: paragraphs 13.4 to 13.22
- trees and woodland: paragraphs 13.23 to 13.29
- amenity and nature conservation: paragraphs 13.30 to 13.48
- hard end uses: paragraphs 13.49 and 13.50.

Agriculture

13.4 The planning authority (LPA) consults MAFF (WOAD in Wales and SOAEFD in Scotland) when preparing aftercare conditions for agriculture. Aftercare works may be specified in a condition, but the LPA frequently require the operator to prepare and agree an aftercare scheme[102].

13.5 Agricultural management requires consideration of two main subjects

- *soil husbandry* - maintaining and improving soil fertility and structure, alleviating compaction, drainage
- *crop production* - choice of cropping and livestock levels, pest control.

The operator should consult MAFF for specialist advice.

13.6 Agricultural aftercare on sites which produce landfill gas must take account of the need to maintain gas pipes, well heads, inspection chambers etc. MAFF expect the aftercare scheme to clearly describe measures to minimise disruption to agricultural operations by gas control systems: see Chapters 6 and 14.

[102] See Appendix G.

13.7 The main practical problems which the operator and his land managers encounter, during the aftercare period and beyond, relate to wet ground conditions. This causes difficulties in carrying out

- cultivations
- fertiliser spreading or spraying operations

and severely restricts the period during which the site can be grazed without poaching. The problem will be exacerbated if engineering systems are maintained and monitored when the ground is wet.

- ***Timing*** and ***co-ordination*** are most important if a spiral of deterioration is to be avoided.

13.8 During the aftercare period, the operator may prefer to let the site to a local farmer or agricultural contractor on an ***agricultural tenancy***. This should have conditions attached relating to the care of the land, such as

- fertiliser applications
- permitted cultivation activities
- stock types and numbers
- grazing periods.

These arrangements may continue beyond the 5 year aftercare period.

Soil husbandry

13.9 Soil fertility should be assessed annually by soil sampling and analysis to monitor the levels of plant nutrients in the soil: see Chapters 8 and 9. The soil analysis results indicate the most appropriate fertiliser to apply, and the rate of application. Liming and fertiliser recommendations are usually based on ADAS indices, derived from standard soil analyses, which indicate the level of lime or fertiliser which should be applied.

13.10 Heavy use of fertilisers containing ammonia or nitrates should be avoided, particularly in nitrate-sensitive areas of the country, even though this is the quickest way of increasing the productivity of disturbed soils. Other methods of increasing the nitrogen level in the soil should be used, such as legumes and organic soil conditioners.

13.11 The organic matter content of restored soil must be built up (see Chapter 8), and local sources of organic manures should be investigated. This includes sewage sludge, poultry manure or manure from stock or horse enterprises. If sewage sludge is to be used, heavy metals analysis should be carried out[103]. The operator should seek specialist advice before agreeing to a programme of sewage sludge treatment on agricultural land.

[103] The Sludge (Use in Agriculture) Regulations 1989.

13.12 Compaction caused by the soil spreading machinery is relieved during the initial restoration works, but restored soils become re-compacted with time by

- the passage of maintenance equipment
- the movement of finer soil particles into soil pores.

This results in a gradual reduction in the natural drainage within the soil, and surface waterlogging and diminution of soil fertility will follow.

13.13 During aftercare the operator may carry out spiking, soil slitting or subsoil ripping to reduce compaction. He should take account of the disruption these techniques cause to other agricultural operations such as hay or silage making. Subsoil ripping during aftercare and beyond should be no deeper than the initial ripping and should therefore not affect landfill gas pipes.

- **The depth of gas pipes in the soil should always be checked prior to commencing any deep soil cultivations.**

13.14 Agricultural field drainage systems may have been installed soon after soil placement; but if not, a regular review of soil conditions should be carried out during the aftercare period to assess if and when drainage should be installed.

13.15 Surface wetness observed during the aftercare stage should be carefully investigated to discover whether the installation of underdrainage per se would provide a cure. The problem might be due to poor soil structure or compaction within the profile, and will not be directly solved by underdrainage.

13.16 Delaying laying drainage pipes for up to three years, until the initial landfill settlement has taken place, reduces the problems of disturbance to the pipes. This must be balanced against the improvements in soil structure which will result from the drainage system. It may be advisable to install a short term sacrificial system to promote soil improvements.

13.17 The aftercare scheme usually requires a surface water drainage design: see Chapter 9. A programme for digging ditches and laying drains should be agreed with MAFF and implemented during the aftercare period. The programme should take account of

- timing of agricultural operations, such as sowing and harvesting
- soil conditions.

13.18 On-going ditch maintenance will be necessary throughout the aftercare period and beyond.

Crop production

13.19 The choice of cropping is influenced by local cropping patterns, to give a crop which suits the local farming pattern and which neighbouring farmers are prepared to manage. A crop must be chosen which does not require activities which may damage the soil structure: see Chapter 9. Crop rotation or the use of pioneer crops are useful to improve soil structure and fertility prior to long term arable cropping. MAFF recommend grass as a most suitable pioneer crop for restored land.

13.20 Agricultural grassland is cut for hay or silage, or grazed, or both. Grazing periods and stock levels must be controlled so that

- over-grazing does not occur
- the site is not grazed by cattle during the winter when poaching will occur.

On grazed sites the operator must see that fences, gates and water supplies are regularly inspected and maintained. Sheep are preferable to cattle because they cause minimal effects on soil structure. Horses should not be kept on restored land because they graze selectively and damage the sward by trampling, which leads to deterioration of the sward.

13.21 After 5 to 7 years the operator should consider re-cultivating and re-seeding agricultural grassland to introduce new grass cultivars and legumes. This procedure, known as grass ley cropping, also returns organic matter, as grass and roots, to the soil.

13.22 Pest control, using herbicides and insecticides, may be necessary from time to time.

Trees and woodland

13.23 Trees, whether planted for landscape integration or as amenity or commercial woodland, require continuing management for at least the first 10 years after planting. The type of management depends on the objectives of the tree planting.

- *Nature conservation* - remove invasive weed species and encourage woodland ground flora.
- *Amenity and public access* - construct and maintain footpaths and bridleways, grass cutting and litter control.
- *Commercial plantations* - remove unwanted woody vegetation, prune lower branches to improve timber quality, and undertake a programme of thinning to increase the growth of those remaining.

The operator should seek the Forestry Authority's advice on managing commercial woodland.

13.24 Long term woodland establishment should be guided by a management plan. The 5 year aftercare period should include a review to act as a prompt to formulate a 5 year management plan for the established trees. This ensures continuity of management which is essential for satisfactory development. The management plan should include the

- objectives for management - listed by priority
- rationale for woodland management - woodland type and desired characteristics for each area of woodland
- objectives for open space within the tree areas and its management
- detail and timing of silvicultural operations within the plan period
- responsibilities, resource requirement and sources.

The operator should ensure that the management plan is handed on to the long term land manager or owner.

13.25 Early management is important to establish vigorous and successful trees which will require less management in future years. The aftercare conditions in the planning permission usually require weed control, fertiliser and beat-up. Weed control and fertiliser applications may be necessary beyond the aftercare period, albeit less frequently (every 2 - 3 years rather than annually).

13.26 Once the operator has established amenity woodland, he should manage it so as to

- increase species diversity
- increase structural diversity.

13.27 Species diversity is increased by

- planting shrub and understorey species, if not included in the original planting mix
- favouring natural colonisation
- removing trees of a dominant species or which were planted as a nurse to slower-growing long term species.

13.28 Regulating structural diversity is a long term aim assisted by

- careful choice of species
- thinning as the plantation develops to create clearings
- coppicing (felling to leave a stump which will re-sprout to give a multi stem plant).

The development of a graded woodland edge can be encouraged by delayed shrub planting or by giving less fertiliser to plants at the woodland edge.

13.29 Plantations may continue to need protection from grazing farm animals and rabbits. Woodlands where public access is encouraged must be regularly inspected for damage and litter, and remedial action taken as necessary. As the woodland develops, firebreaks must be kept mown to reduce the risk of fires spreading.

Amenity and nature conservation

13.30 All short and long term management operations in amenity and nature conservation areas should be guided by a management plan. Some ecological monitoring may be required to assess the results of the management operations. The management plan may form the basis for a legal agreement or *planning obligation*[104].

13.31 The management plan should identify different landscape or vegetation types within the site. It should include

- short term and long term objectives for each area
- management operations necessary to achieve the objectives
- estimate of staff and financial resources required to undertake the management programme.

13.32 In preparing the management plan the operator should seek specialist advice from English Nature, the local authority conservation unit, local nature conservation societies and local ecologists. The plan should outline the works to be carried out during the aftercare period and beyond.

Amenity

13.33 Maintenance regimes for amenity sites are highly site specific and vary according to the aims and objectives for the site.

- Thus urban sites may need intense maintenance to cope with high population pressures.

Untidy areas can rapidly become a collecting ground for litter and encourage mis-use, especially on older local authority landfill sites with a long local history of unauthorised fly-tipping which is difficult to discourage. In other situations such areas of longer grass may be left to encourage wildlife.

13.34 Amenity management may be carried out by the local authority, unless the site has been restored as a private leisure facility. Local authorities are obliged to put grounds maintenance out to compulsory competitive tender (CCT) which reduces their flexibility to vary either the area or the maintenance regime included in their existing schedules. If the operator wishes to transfer his site to the local authority, their staff and financial constraints mean that he will probably need to make financial provision for continued site maintenance.

[104] Section 106 of the Town and Country Planning Act 1990.

13.35 Short term management operations on sites restored for amenity after-uses are principally grassland management, comprising fertiliser applications, weed control and grass cutting or mowing. Formal and informal sites also require attention to access points, paths, margins, fences and litter removal.

13.36 During the first 5 years the fertiliser requirements should be determined by regular soil sampling and analysis. Grass which is required to resist wear caused by intensive use requires a fertile soil and regular fertiliser applications will be necessary. A balanced compound fertiliser should be applied in the spring to supply phosphate and potash. Regular top dressings of fertiliser may also be required on sports pitches and intensively-used areas throughout the summer and autumn.

13.37 Weed control to eliminate invasive perennial weeds may be needed during the first two or three years until the sward establishes. The operator should use a selective herbicide[105].

13.38 The frequency and height of grass cutting depends on the use to which the site is being put. There are three broad cutting regimes, according to frequency of cut.

- For open space and casual recreation the operator should cut at least twice per year, once in June and once in September, to keep the grass to a maximum height of about 150mm.
- On areas of more intense use the operator may need to make monthly or fortnightly cuts, maintaining the grass at a height of about 75mm.
- On sites which combine amenity with nature conservation, differential mowing maintains the species diversity in the wild flower areas.

13.39 Infrequent cutting is carried out using a tractor-mounted flail mower or forage harvester. Flail or gang mowers are used for more frequent cutting.

13.40 For recreation grounds additional maintenance operations include surface aeration by spiking or sand slitting, light rolling, sward renovation and marking out.

Nature conservation

13.41 Nature conservation after-uses generally require low maintenance, but some work is needed and the operator should make financial provision for it.

13.42 On sites where areas of existing wildlife interest are protected while the site is operational, the management plan should be in place from the start, forming part of the initial restoration proposals. Maintaining areas of existing nature conservation throughout the life of the site

- ► demonstrates the operator's commitment to nature conservation
- ► preserves plant material which can be used later to establish similar habitats on restored areas

[105] The requirements of the Control of Pesticides Regulations 1986 apply.

- encourages fauna to remain on the site and thus migrate or be translocated to restored areas

- maintains locally important wildlife sites, such as bird feeding or roosting areas, thus reducing adverse ecological impact caused by the site.

13.43 All nature conservation sites with public access should be regularly inspected. Access points, paths and fences must be maintained in good condition and litter removed as necessary.

13.44 Natural ecosystems are constantly evolving and management is essential to maintain a specific ecological habitat. The operator should involve specialists and seek their advice. The following paragraphs offer general advice on maintaining sites for nature conservation.

i *Species-rich grassland*

13.45 Species- rich grassland should be mown as a hay meadow to maintain species diversity. The site should be cut in late July-early August after the flowers have set seed. The action of turning the cut grass to allow it to dry out will encourage the wild flower seeds to drop back onto the ground. Sites may be grazed in the autumn, or a second cut of hay taken.

13.46 The operator should not use fertilisers or broadcast herbicides. Persistent perennial weeds should be spot treated with a suitable herbicide. If the site is grazed, stock levels must be very carefully controlled.

ii *Heathland*

13.47 Establishing heathland should not be grazed by cattle, sheep or horses because this is very detrimental to young heather. Such sites should be protected from both grazing and rabbits to encourage vegetation establishment. Invasive weeds should be controlled and the grass cut to promote heather growth.

iii *Wetlands and ponds*

13.48 Wetlands and ponds must be maintained to eradicate undesirable species. Vigorous aquatic species and water margin plants, such as reedmace or bulrush, rapidly become dominant at the expense of more interesting species and must be controlled. The pond may have to dredged periodically to prevent it silting up.

Hard end uses

13.49 Landscaped areas on sites which are otherwise restored for hard end uses should be maintained using normal vegetation establishment procedures. These include

- annual fertiliser applications to shrubs and trees for the first five years to encourage vigorous growth

- annual inspection of standard trees to check the condition of tree ties and stakes

- weed control by herbicide applications or, in shrub beds, by spreading a mulch of bark, wood chippings or peat substitute to discourage weeds.

13.50 The site should be inspected regularly for vegetation damage, and replacement of dead, dying or badly damaged plant material will maintain the site in an attractive condition. Litter should be collected and removed. All paving and fences should be maintained and repaired if necessary.

Chapter 14

Post-closure management of engineering systems during aftercare

Introduction

14.1 The operator remains responsible for environmental protection of the site during and after the aftercare period until the certificate of completion is issued and the waste management licence surrendered[106]. He must take steps to ensure that the pollution control engineering systems remain effective. The monitoring and maintenance works which this entails will potentially affect aftercare.

14.2 The chapter describes how aftercare and after-use may be affected by

- the long term protection of the pollution control engineering systems
- monitoring and maintenance works
- decommissioning and removing redundant systems.

14.3 The chapter deals chiefly with the cap, and the landfill gas and leachate control systems. The maintenance of vegetation on the restored site is described in Chapter 13.

Protection of systems

14.4 The operator must protect the pollution control systems throughout the post-closure period. These include

- the cap
- the landfill gas control system
- the leachate collection, treatment and disposal system
- groundwater monitoring boreholes.

14.5 **Above-ground components**, such as monitoring boreholes, wellheads, leachate pumping manholes are at greatest risk of damage.

- If these are located in areas of intensive or regular management for agriculture or recreation, they may be damaged by cultivation, harvesting and grass cutting machinery.
- If they are close to the ground they may become difficult to find for inspection and monitoring purposes, and may, in time, become buried by soil after repeated cultivations.

The operator must **mark** the location of manholes above the level of the grass or standing crop. Manhole covers and surrounds should be robust enough to withstand damage.

[106] See WMP26A Landfill Completion.

14.6 The most effective protection measure is to design the system so that above ground components are not sited in vulnerable locations. This is possible on new sites, but existing sites may not allow the same flexibility of design. The after-use design should be modified, if necessary, to reduce the risk of inadvertent damage by

- altering the land use
- changing the field boundaries to coincide with wellheads and manholes.

14.7 Some sites are prone to wilful damage; the site compounds and gas wells are natural targets. Damage includes theft of installations or components, breakages, and puncturing of HDPE liners resulting in uncontrolled escape of leachate from lagoons, etc.

- Secure fencing may be sufficient to prevent vandalism and theft on some sites; 24 hour security may need to be considered for gas compounds damage could have serious health and safety consequences.

14.8 The above-ground sections of passive venting columns also attract maltreatment. They should be tall enough to prevent the venting flammable gases from being lit, with the attendant risk of fire and injury, and robust enough to withstand damage. Passive gas venting is no longer recommended and this potential risk is reducing.

14.9 The operator must keep construction (*as built*) records of underground systems which must be referred to before any subsequent excavation and deep cultivation works. On new sites the soil depth must be sufficient to prevent damage by subsoil ripping, mole ploughing or laying field underdrainage. On old existing sites this may not be the case. Site documentation, such as the site manual (see Chapter 7), should record the location and depth of underground pipes and this information must be made available to anyone carrying out works during the post-closure period.

- All farmers and maintenance teams who work on the site during the aftercare period must make full and competent use of the documentation that the operator supplies.

Maintenance operations

Landfill cap

14.10 In the past the maintenance requirements of the cap have been minimal once the soil has been replaced. On sites which are engineered for accelerated stabilisation, maintenance of the leachate recirculation system (flushing, cleaning out and repair) will result in the cap being disturbed. Remedial works to the cap may be necessary to repair cracks and holes if these are serious enough to increase water ingress so that the leachate collection and treatment system becomes overloaded.

14.11 Serious differential settlement leads to ponding and waterlogging in low spots over the cap, which increases the risk of water penetration at that point. The operator may need to correct this by stripping the soil before lifting the cap to place additional fill in the low area. When the cap is replaced the repaired area must be properly sealed to the original cap. On non agricultural sites where the risk of groundwater contamination is low, such areas may be left seasonally waterlogged for added wildlife interest.

Landfill gas systems

14.12 The operator should monitor the perimeter boreholes regularly to detect gas migration off site. He should also monitor the gas wells for performance and gas yield, especially if the gas is being used to generate electricity, or being exported for energy. The operator must maintain access to the perimeter boreholes throughout the aftercare period. The location of boreholes and wells, and the agreed access route must take account of the requirements of the after-use, especially in agricultural fields.

14.13 The operator may need to carry out works to the original system at any time throughout the aftercare period, such as

- remedial work to wells and pipework
- modifications to the system including drilling new wells
- extending the system to new gas fields
- changing the system from passive to active extraction (or vice versa)
- replacing the flare with biological oxidation or dispersal unit
- decommissioning and removing redundant structures.

Information on landfill gas systems and their impact on restoration is provided in Chapter 6 and Appendix E[107].

14.14 Work to the wells and pipe network will almost certainly affect aftercare, and is potentially very damaging. The steps which must be taken to minimise the severity of this impact, including interim restoration, are described in Chapter 7. If unavoidable modifications to the system are required on land that is in aftercare, the operator should ensure that the measures given in Table 14.1 are followed. These will reduce the impact and make reinstatement more successful.

14.15 The gas compound is likely to remain on site until the end of the post-closure period when it should be decommissioned and all the redundant equipment removed. At this time other parts of the system, such as valves, pumps and other salvageable equipment should also be removed from site. The operator should arrange these works to cause minimal disturbance to the after-use. Access to site and demolition works must be restricted to an agreed area, and the timing should not conflict with

- farm activities, such as cultivation and harvesting
- wildlife breeding periods.

Table 14.1 Steps to minimise adverse effects on aftercare and after-use during remedial works to engineering systems

Item	Action
Timing/ programming	Agreed and organised so as to cause least impact on aftercare and after-use.
	Wherever possible works must be carried out when soil conditions are dry.
Supervision	Works must be carefully supervised at all times to ensure that the works are carried out in accordance with this specification.
Access and working area	Minimum practical working area and suitable access must be agreed with engineers and contractors, and must be fenced off from the rest of the site to contain the area of disturbance.
Soil conditions	Wherever possible works must be carried out when soil conditions are dry.
Machinery/ equipment	Use plant which will not cause soil compaction during soil stripping operations or where soils cannot be stripped.
Soil conservation	All topsoil and subsoil must be stripped and stored separately, and replaced in the correct sequence, particularly if wet weather working is unavoidable.
Agricultural areas	Delay works until any crops have been harvested, or hay taken, if at all possible.
Woodland areas	Engage a silviculturist to prune back any trees and shrubs which are outside the working area but close enough to the boundary to be at risk of damage, prior to commencement of works.
Nature conservation areas	Programme the works to avoid bird breeding periods (Spring-early Summer), move important plant species to a safe area.
Cultivation and seeding	Must be carried out by landscape contractors to the same standards as the original works, to include reinstatement of field drainage, hedges, fences, replanting of woodland, habitat reinstatement.

Localised reinstatement works should be carried out if necessary. The planning conditions may require the compound area to be restored, and the operator must make provision for this. The operator may have to import soil to restore areas of former hardstanding, and landscape the area in accordance with the approved landscape and restoration design.

Leachate systems

14.16 Fixed leachate monitoring points and the leachate pumps must have regular attention. The operator should maintain access to these points. Remedial works or modifications to the system which affect aftercare or the after-use should be carried out in accordance with Table 14.1.

14.17 If the leachate collection system becomes less efficient, the head of leachate over the liner will build up. In this event, the operator must redrill the original wells or drill new wells to supplement the established system. Wherever possible, new wells should be located at the edges of fields and in areas which are not intensively managed for agriculture.

14.18 When the leachate collection and treatment system is no longer required the operator should

- pump the lagoons and underground collection chambers clean and dry
- backfill them with inert material
- remove the pumps from the site
- remove the treatment plant from the site
- clear and restore the compound, to the same standards as the gas compound (paragraph 14.16 above).

This clearance may be specified in the planning conditions; but the operator should expect it and plan for it, practically and financially, whether it is or not.

Abbreviations

ADAS	Agricultural Development and Advisory Service
BSI	British Standards Institution
BTCV	British Trust for Conservation Volunteers
DoE	Department of the Environment
HSE	Health and Safety Executive
ICE	Institution of Civil Engineers
ICRCL	Interdepartmental Committee on the Redevelopment of Contaminated Land
IWM	Institute of Wastes Management
MAFF	Ministry of Agriculture Fisheries and Food
NAWDC	National Association of Waste Disposal Contractors (now Environmental Services Association)
NRA	National Rivers Authority
SOAEFD	Scottish Office Agriculture Environment and Fisheries Department
WOAD	Welsh Office Agriculture Department

Glossary

The glossary definitions apply to this WMP only.

AFTERCARE	The work done after replacement of the soil to bring the land up to the required standard for the after-use, that is cultivating, fertilising, planting, drainage and otherwise treating the land.
AFTER-USE	The intended use of the restored land.
AMENITY	A land use which is not productive agriculture, forestry or industrial development; can include formal and informal recreation and nature conservation.
AQUIFER	A geological stratum or formation that is capable of both storing and transmitting water in significant amounts.
BEAT-UP	Replacing the dead and dying plants in a planting scheme
BIODEGRADATION	The ability of natural decay processes to break down man-made and natural compounds to their constituent elements and compounds, for assimilation in, and by, the biological renewal cycles.
BIOREACTIVE WASTES	Wastes which are capable of undergoing biological degradation.
BIOTECHNOLOGY	The exploitation of biological processes for industrial and other purposes.
BOREHOLE	A hole drilled to obtain samples and to monitor for landfill gas migration.
BUND	A small bank of soil or other inert material used to define limits of cells or phases or roadways. Not a structural embankment but may be a permanent part of a landfill base.
CAPPING	The covering of a landfill, usually with low permeability material. Permanent capping is part of the final restoration following completion of landfilling/tipping. Temporary capping is an intermediate cap which may be removed on resumption of tipping.
CELL	The compartment within a landfill in which waste is deposited. The cell has physical boundaries which may be a low permeability base, a bund wall and low permeability cover.
CHEMICAL FERTILITY	Of soils: fertility as a function of the rocks from which they were formed and their organic matter content.

COMPACTION	The compression and volume reduction of waste materials and soils.
CONTAMINATION	The addition of chemicals to groundwater, watercourses or soils at concentrations that can be measured and are significantly higher than background concentrations.
COVER	Material used to cover wastes deposited in landfills. Daily cover is used at the end of each working day to prevent odours, wind-blown litter, insect or rodent infestation. Final cover is the layer, or layers, of material placed on the surface of a landfill during its restoration.
DESIGN	The formulation of the plan for the landfill project, including all the details and drawings for the particular site.
EARTHWORKS	Engineering work associated with the movement of soils and materials on a landfill.
ENVIRONMENTAL IMPACT	The effect of any operation on the surrounding environment.
EVAPOTRANSPIRATION	The combined effects of evaporation and transpiration.
FIELD CAPACITY	The amount of water that may be retained in soil pores against gravity after saturation and draining.
GAS COMPOUND	Monitoring station located adjacent to the landfilled area; usually includes a flare stack, utilisation equipment, pumping station, dewatering points to remove condensate, and monitoring equipment.
GAS SYSTEM	System of pipes, wells and vents which are installed in the landfill to control gas migration or to extract gas for utilisation, or both.
GROUNDWATER	The mass of water in the ground within the saturated zone, occupying the total pore space in the rock and moving slowly downhill where permeability allows.
HEAVY METALS	Elemental metals having a high atomic mass and properties that may be hazardous in the environment. The term usually includes the metals copper, nickel, zinc, chromium, cadmium, mercury, lead, arsenic, and may include selenium and others.
HOLISTIC	Of a process or project in which action in one part affects all the others.
IMPERMEABLE	Of a material, natural or synthetic that has the ability to resist the passage of fluid. Impermeability is usually expressed as the coefficient of permeability. Permeability is not absolute: a coefficient of permeability of 10^{-9}m/sec

	for water is often used as a standard for landfill lining materials. The coefficients of permeability of materials for gases are likely to be greater. See also **PERMEABILITY.**
INERT MATERIALS	Materials that will not undergo significant physical or chemical reaction or biodegradation within the landfill.
INFILTRATION	The downward flow of water through the soil pores into the subsurface strata or the spoiling of an aquifer by pollutants.
INTERIM RESTORATION	Establishment of vegetation following replacement of part of the full subsoil depth (partial soils replacement) by stone-picking and light cultivations followed by sowing grass seed to establish a grass cover.
LANDFILL	The engineered deposit of waste into or onto land.
LANDFILL GAS	A by-product of the digestion by micro-organisms of putrescible matter in waste deposited on landfill sites. It comprises chiefly methane and carbon dioxide with trace concentrations of other gases. The proportions of methane and carbon dioxide vary according to the age of the waste material and the stage of biodegradation.
LANDFORM	The profile of the completed surface of a landfill.
LANDRAISING SITE	A waste disposal site which is above the height of the surrounding land, usually contained within perimeter bunds.
LEACHATE	Liquid that has seeped through a landfill and has thus extracted substances from the deposited wastes.
LINER	A natural or synthetic membrane, used to line the base and sides of a landfill site to reduce the rate of leachate and gas emissions.
MONITORING	Obtaining information about conditions and processes in a landfill. Methods include physical examination, measurements by portable instruments, and analysis of samples.
OPERATOR	The person or company who is responsible for using or maintaining the landfill, together with his agents and contractors.
OPERATIONAL SITE	A site still in use; or a site closed temporarily, for whatever reason.
OVERBURDEN	The geological material from which the soil has formed; sometimes referred to as soil parent material.

PERCHED WATER	An accumulation of liquid at a level above that of the adjacent water table. Often caused by zones of low permeability strata (or wastes) which inhibit downward percolation.
PERMEABILITY	A measure of the rate at which a fluid will pass through a medium. The coefficient of permeability of a given fluid is an expression of the rate of flow through unit area and thickness under unit differential pressure at a given temperature. Soils may be referred to as slowly permeable.
PHASE	Of a landfill: an operational area distinguished from other areas in space, or time, or both.
PHASING	The planned development, operation and restoration of a site in a series of separate, though usually adjacent areas. The phase of a landfill is a prepared operational, temporarily restored or restored area.
POACHING	Trampling the land to mud (usually by farm stock).
POLLUTION, POLLUTANT	The addition of materials or energy to an existing environmental system to the extent that undesirable changes are produced directly or indirectly in that system. A pollutant is a material or type of energy whose introduction into an environmental system leads to pollution.
POST-CLOSURE MANAGEMENT	Works done to maintain pollution control systems and monitor their effectiveness during the post-closure period.
POST-CLOSURE PERIOD	The period which follows cessation of landfilling before the certificate of completion is issued.
RESTORATION	The process which will return a site to a condition suitable for its proposed after-use; includes design, initial landscaping works, soil spreading and aftercare.
SETTLEMENT	The amount by which a landfill surface sinks below its original level due to compaction by its own weight, and degradation of the waste.
SOIL	The naturally occurring material on the surface of the earth which serves as the growth medium for plants (see also topsoil, subsoil, overburden).
SOIL HUSBANDRY	The care of soil through management practices such as cultivations and fertiliser amendments.
SOIL RIPPING	Disturbance of the soil layers by drawing a rigid tine through the profile to promote drainage and aeration.

SOIL STRIPPING	The staged removal of soils from an area to be worked.
SOIL STRUCTURE	The arrangement of solid (or mineral) soil particles and pore spaces.
STABILISATION	As applied to landfill this term includes the degradation of organic matter to stable products, and the settlement of the fill to its rest level. The process can take many years to complete. The term also refers to the use of plants and or geotextiles used to prevent soil erosion from the surface of a landfill or spoil heap.
SUBSOIL	The material immediately below topsoil, usually extends to 1 - 1.2 m in depth but may be shallower or absent altogether.
SURCHARGE	To fill a landfill above final contours to allow for subsequent settlement.
SUSTAINABILITY	Returning the contents of a landfill site to the environment in a controlled manner, at a rate which the environment can accept without harm, generally using pro-active measures over a limited timescale to diminish polluting capability, in a way which does not leave a long term legacy of active monitoring and management.
TOPSOIL	The darker, organic-rich surface horizon of the soil profile, usually cultivated and 200 - 300mm thick.
UNDERSTOREY	Level of cover lower than forest trees.
VENTING, ACTIVE	The removal of landfill gas by forced extraction.
VENTING, PASSIVE	The natural movement of gas from a landfilled area of wastes to atmosphere usually assisted by porous drainage media.
VOID SPACE	The capacity within a landfill available for waste, together with cover, construction material, capping engineering and restoration layers.
WASTE, CONTROLLED	Under the Environmental Protection Act 1990, section 75(2), includes a) any substance which constitutes a scrap material or an effluent or other unwanted surplus substance arising from the application of any process; and b) any substance or article which requires to be disposed of as being broken, worn out, contaminated or otherwise spoiled, but does not include a substance which is an explosive within the meaning of the Explosives Act 1875.
WATER TABLE	Top surface of the saturated zone within the aquifer.
WINDTHROW	Blowing down of trees by wind.
WORKING AREA	The area of the landfill in which waste is currently being deposited.

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There is a large amount of published information on landfill restoration and the related topics of reclamation of mineral extraction sites and landfill engineering. This bibliography is limited to publications which provide

- general overviews of all or part of the subject area
- specific information or advice on a more restricted topic.

It includes some publications where readers unfamiliar with a particular topic will find helpful information.

The publications are grouped by chapter, but Chaper 1 (Introduction) also includes some which are also relevant to many other chapters. Readers seeking references to a particular topic covered by a particular chapter may also wish to consult these.

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APPENDICES

APPENDIX A

SOILS

A1 Basic soil properties

A2 Chemical properties - chemical fertility, soil testing, lime and fertiliser requirements

A3 Biological properties

A4 Soil survey and calculation of soil resources

A5 British Standard BS 3882

A6 Soil movement diagrams

APPENDIX A SOILS

A1 Basic soil properties

Colour

A1.1 Most soils are black, brownish or greyish in colour, sometimes with colour mottling in shades of brown and grey. Colour varies with moisture content, and, by convention, the soil colour is reported when it is moist. The following guidelines generally apply

- The greyer and more prominently mottled the soil, the more likely it is to be periodically waterlogged, or at least have formed under waterlogged conditions (e.g. Soil B in Table A.1).

- The darker the colour the higher the organic matter content (e.g. see Table A.1, Soil A is an organic rich topsoil, B and C are not).

A1.2 Soils which appear from their colour to be mixtures of two or more materials should be treated with suspicion and expert advice, possibly with analytical information should be sought (e.g. Material C in Table A.1)

Texture, stoniness, structure, porosity, compaction, consistency

A1.3 A fundamental property of a soil is its texture which is defined as the relative proportions of sand (0.06 - 2.00mm), silt (0.002 - 0.06mm) and clay (0.002mm). Soil with a more or less equal mixture of sand, silt and clay are described as `loamy'. Soils with large amounts of sand are sometimes referred to as `light' or `coarse textured', those with large amounts of clay `heavy' or `fine textured'.

A1.4 Detailed soil descriptions use more sophisticated textural classes such as `sandy clay loam', `loamy sand', etc. Sometimes the sand is subdivided into fine, medium and coarse and the size of the dominant fraction included in the texture name, e.g. `fine sandy loam'.

A1.5 In practice the textural class can be determined with reasonable accuracy by finger assessment in which the relative proportions are subjectively assessed from the feel of a moist soil sample. Sand imparts grittiness, silt a smoothness, clay a stickiness while loams feel doughy.

Table A.1 Some typical soil descriptions

	A	B	C
Location.	Topsoil in field 1083.	Unknown material in Storage Heap 3.	Material offered by McRae Soil Resources Ltd.
Colour.	Dark brown.	Brown with ochreous and grey mottles.	Greyish brown with black patches.
Texture.	Medium silty clay loam.	Clay.	Clay.
Stoniness.	About 5%, mostly less than 20mm diameter.	No stones.	About 10-15% including pieces of concrete, brick and asphalt.
Structure, etc.	Well developed.	Weakly developed coarse angular blocky on outer surface. Massive in main bulk of heap.	Medium granular. Weakly developed medium angular blocky
Water relations.	Slightly moist and friable at time of inspection, known to be well drained and non-droughty (moderate to high available water capacity); friable.	Wet and plastic at time of inspection. Mottling and massive structure suggests slow permeability and poor drainage. Likely to be non-droughty.	Sample provided is dry and very firm, but site from which derived believed to have lain wet last winter.
Organic matter.	Moderate - 5.4% by laboratory analysis.	Very low - 0.3% by laboratory analysis.	Nil - no laboratory data.
Chemical fertility	pH 7.8 (slightly calcareous). Avail P - index 3. Avail K - index 0. Avail Mg - index 0.	pH 5.4. Avail P - index 0. Avail K - index 0. Avail Mg - index 0.	pH 3.5. Avail P - index 0. Avail K - index 0. Avail Mg - index 0.
Comments	Good quality topsoil, a little on the heavy side. Will probably need application of K and Mg fertiliser.	Probably subsoil or overburden. Poor quality. Likely to be poorly draining.	Highly suspect due to content of foreign bodies. Laboratory analyses for possible toxic components needed.

A1.6 The main characteristics of the three main soil types are as follows:

- **Sandy soils** tend to dry out quickly so that crops growing on them suffer drought, are often inherently acid and infertile (but this can be corrected by lime and fertiliser), may suffer from erosion by wind or water, are light and easy to cultivate and also to move by mechanised soil handling.

- **Clayey soils** are often wet and heavy and frequently suffer from poor drainage, are more fertile than sandy soils, are more difficult to cultivate and to move by mechanised soil handling.

- **Loamy** and **silty** soils have good moisture holding capacity but usually drain easily, are usually inherently fertile and moderately easy to cultivate, can easily be damaged, especially silty ones.

A1.7 Particles larger than 20mm are classed as stones. They dilute the volume of the actual soil and those larger than 50 or 60mm can interfere with cultivation operations.

A1.8 In most soils the individual particles of sand, silt and clay tend to stick together to form larger compound particles called **aggregates** or **peds** between which are planes of weakness along which the soil will separate if it is pulled apart. This property is called the **soil structure**.

- It is normally described according to the size and shape of the aggregates and the degree to which the property is developed e.g. `Well developed medium angular blocky structure' (e.g. A and C in Table A.1).

Soils which have no structure can be either **massive** i.e. one large block with no planes of weakness - typical of clayey subsoils, for example B in Table A.1, or **single grain**, typical of sandy soils where the particles cannot stick together to form aggregates.

A1.9 Important factors in soil structure development and maintenance are

- organic matter
- activity of roots, earthworms and micro-organisms living in the soil (topsoils are well structured)
- wetting and drying (waterlogged soils are poorly structured)
- texture (clayey soils are potentially well structured unless waterlogged, while sandy and silty soils usually have weakly developed structure easy damaged by cultivations or mechanised handling).

A1.10 About half the volume of soil is void space. Thus the **bulk density** of a typical soil is about 1.3 gcm^{-1} (about 50% **porosity**). Loose soils, e.g. recently cultivated, can have bulk densities less than 1 (more than 60% porosity). Conversely, massive clayey soils and especially soils which have been compacted by the passage of heavy machinery can approach or even exceed bulk densities of 2 (less than 25% porosity).

A1.11 In practice bulk density and porosity is rarely determined or included in descriptions of soils. More commonly a related property, soil consistence is described. This refers to how the soil behaves when manipulated and subjected to pressure by hand. Terms such as

- loose, brittle or friable (crumbly) imply a relatively non-compacted soil (e.g. A in Table A.1),
- firm, hard or, when moist, plastic (e.g. B and C in Table A.1) imply a relatively dense, probably slowly permeable and perhaps excessively compacted soil.

A1.12 Soils tend to become softer and more easily manipulated as they become wetter. Thus a soil might be described as hard when dry, friable when slightly moist and plastic when wet. The point which a soil passes from the friable (crumbly) state to the plastic state is known as the **plastic limit** and is an important characteristic for assessing the suitability of soil for mechanised handling (see below).

Water relationships - available water, drainage

A1.13 Soil water relationships are determined by the pore-size distribution. Pores larger than about 0.05mm are filled with water when the soil is wet, but empty under the force of gravity and become air-filled. These larger pores, typically between soil aggregates, provide much of the soil's **permeability.** They are also exploited by roots and are the living spaces for the soil flora and fauna. **Compaction** reduces the volume of larger pores, thus reducing the permeability to both air and water, and restricting root growth.

A1.14 Capillary sized pores between about 0.001 and 0.05mm, which occur typically within aggregates, store **available water** for plants to withdraw as needed. Pores smaller than about 0.001mm hold water too tightly for plants to extract.

A1.15 The higher the available water capacity the better the soil, especially in the drier parts of the country.

- Coarse and medium sandy soils tend to have large pores and so do not hold much available moisture
- Fine sandy, silty and loamy soils can hold substantial amounts of available water.
- Clayey soils hold large amounts of water, but only a portion of it is available to plants so that clayey soils tend to have lower available water capacities than silty and most loamy soils especially if poorly structured.

The presence of organic matter confers a higher available water capacity on topsoils (see below) than similarly textured subsoils.

A1.16 Poorly drained or waterlogged soils are produced where excess water cannot drain away under gravity. The nearer the surface the waterlogging occurs and the longer it lasts the worse the drainage.

A1.17 Poor drainage can be caused either by a high water table or by the presence of a slowly permeable layer within the profile. Slowly permeable soils, typically heavy textured, can occur in any topographic position. Poorly structured or compacted soils created by poor soil management or by mechanised handling are often poorly drained.

A1.18 Waterlogging is harmful to plant roots (excludes oxygen) and makes soils too soft for traffic to pass safely over them. Waterlogging also causes various chemical changes, notably to iron compounds in the soils producing grey colours and/or grey and rusty brown mottling, referred to as gleying. Thus the presence of gleying and other evidence such as massive structure and/or clayey texture indicates soils likely to be poorly drained (e.g. Soil B in Table A.1).

Organic matter

A1.19 Organic debris is added to soils in the form of

- dead leaves and roots
- animal excreta from both larger animals and the small soil animals digesting the added organic material
- as the dead cells of micro-organisms living in the soils, most of which are involved in breaking down the organic material.

Breakdown of organic material releases plant nutrients so completing the cycling of nutrients from soil to plants and back to the soil for the next generation of plants and produces a relatively stable, well decomposed end product called humus.

A1.20 Organic matter addition and decomposition is a surface process producing the darker coloured topsoil where the organic matter may be up to about 5% by weight, compared with 0.5% or less in the underlying subsoil. Cultivated topsoils usually have a clearly marked lower boundary about 200 to 300mm from the surface, the normal depth of ploughing. Organic matter content may be estimated from the soil colour but laboratory determination may be advisable. British Standard BS 3882 states that loss on ignition reflects organic matter content although more accurate methods are widely used elsewhere.

A2 Chemical properties - chemical fertility, soil testing, lime and fertiliser requirements

A2.1 Under natural conditions, **chemical fertility** is related to the rocks from which the soil was formed and its organic matter content. However in agricultural soils the chemical fertility is usually increased by fertilisers containing nitrogen, phosphorus and potassium. Some soils can become polluted with toxic substances e.g. heavy metals in some sewage sludges.

A2.2 Most British soils are slightly acid (pH 6) to strongly acid (pH 4 or less). **Calcareous** soils contain free calcium or magnesium carbonate and have pHs around 8. The pH of acid soils can be raised by adding lime and agricultural soils are often limed to maintain the optimum pH for grass (pH6) or arable crops (pH6.5). Land used for trees or natural or semi-natural vegetation is usually not limed unless extremely acid and plant material is selected which is tolerant of the prevailing pH.

A2.3 The reliability of soil testing depends on the sampling procedure. Numerous separate samples (5 per ha or 25 per 10 acres) are taken and mixed together to produce a bulk sample which is representative of the area. The sampling points should be at random but avoiding gateways, paths, disturbed areas and areas where soil conditions may be unrepresentative. A convenient method is to walk a W-shaped path across the sampling area taking 5-6 samples per limb. If a sampling area has an obvious soil boundary across it, each area should be sampled separately. BS 3882 recommends that the maximum area for a single bulk sample should be 5 hectares.

A2.4 Similar considerations should apply to the sampling of soils from storage heaps. BS 3882 recommends bulking together 25 sub-samples (taken from throughout the heap, not just the surface) or submitted as typical of imported material.

A2.5 The simplest tool for the collection of soil samples from a field or storage heap is a screw auger. Normally soil is collected from the top 150mm (6") although for some purposes deeper samples may be taken. The bulk sample should be collected in a polythene bag clearly labelled with the site, date and name of the person collecting it.

A2.6 Soils should be analysed for extractable or available nutrients and for lime requirement by standardised methods (described in BS 3882) which can be interpreted. Soil testing usually includes determination of pH and lime requirement, extractable phosphorus (P) and potassium (K), and extractable magnesium (Mg). Results are given as both mg/l and as an Index (see Table A.2). The Indices are from 0 indicating deficiency, to 9, an excessively high value. Most fertile agricultural soils giving indices from 1 to 4 and horticultural soils from 3 to 6 (e.g. results quoted in Table 8.1). There is no routine analysis for extractable Nitrogen (N) and fertiliser recommendations for this are based on an Index derived from the previous cropping history. For some purposes (e.g. in BS 3882) a laboratory determination of total nitrogen content may be necessary.

A2.7 Soil testing for potentially toxic elements is a specialised procedure and expert advice should be sought (e.g. for material C on offer in Table A.1). Determination of specific electrical conductivity (to indicate the possible presence of excessive levels of soluble materials) and exchangeable sodium percentage (for soils with high electrical conductivities) is one of the factors used to grade topsoils according to BS 3882.

Table A.2 Concentration of extractable nutrients and indices

Index	Concentration of extractable elements in milligrams per litre of soil		
	P	K	Mg
0	0 to 9	0 to 60	0 to 25
1	10 to 15	61 to 120	26 to 50
2	16 to 25	121 to 240	51 to 100
3	26 to 45	241 to 400	101 to 175
4	46 to 70	401 to 600	176 to 250
5	71 to 100	601 to 900	251 to 350
6	100 to 140	901 to 1500	351 to 600
7	141 to 200	1501 to 2400	601 to 1000
8	201 to 280	2401 to 3600	1001 to 1500
9	over 280	over 3600	over 1500

A3 Biological properties

A3.1 Most soil organisms are involved in the decomposition of added organic matter to humus and so are more abundant in the topsoil, especially if fresh organic material has recently been added. Their activities are inhibited by cold, wet, acid and infertile conditions. It is more important to ensure suitable conditions than to try deliberately to introduce earthworms or bacterial inoculants.

A3.2 Topsoils usually contain a bank of dormant seeds which will germinate when conditions are suitable. BS 3882 requires all grades of topsoil to be visually free of propagules (stolons, rhizomes or seeds) of aggressive weeds such as couch grass, red fescue, docks, Japanese knotweed or horsetail.

A4 Soil survey and calculation of soil resources

A4.1 Soil horizon depths are conventionally given in cm (rather than m or mm) from the surface and not directly as horizon thicknesses. Thus a typical profile could be described as:

0 - 24cm	Dark brown medium clay loam (topsoil)
24 - 100cm	Brown medium clay loam, mottled below 50cm (loamy subsoil)
100 - 170cm	Yellowish brown clay (clayey subsoil/overburden)

The thickness of topsoil is 24cm.

The thickness of loamy subsoil is 76cm (from 24cm below the surface to 100cm below the surface).

The average thickness of the remaining clayey material or (depending on circumstances) to be regarded as non-soil overburden is, in this profile, 70cm. Its thickness over the whole site would have to be assessed from a combination of soil survey and geological information.

A4.2 Soil volumes are calculated from the formula:

Volume (m^3) = Area (m^2 or ha x 10,000) x thickness (cm/100)

A4.3 It is very probable that two soil surveyors working independently will produce apparently different soil maps for the same area because each may have classified the soils according to different criteria. Due to the inherent variability of soils and variations in soil sampling methodology independently produced soil maps will differ slightly from each other.

A5 British Standard BS 3882

A5.1 British Standard BS 3882 Specification for Topsoil was published in 1994. It recognises three grades of topsoil, premium, general purpose and economy. The Standard does not cover subsoil. It is not intended (or appropriate) for the grading of in situ topsoil or subsoil. The definitions of the three grades of topsoil are given below, and their characteristics are given in Table A.3.

Premium grade

A5.2 Premium grade is natural topsoil, of high intrinsic fertility, loamy texture and good structure. It has the capacity to be used in situations where it is intended to grow the most demanding plants or where the topsoil may be subject to intensive or frequent cultivation e.g. annual bedding. This high quality may be unnecessary for the majority of topsoil applications where the other grades may be entirely satisfactory.

- Premium grade is generally the most limited in supply.
- If mishandled or badly stored, premium grade topsoil can change to one of the other grades.

General purpose grade

A5.3 General purpose grade includes natural topsoil and premium grade topsoil that has deteriorated due to poor handling, or a manufactured soil which has appropriate qualities. It is capable of being suitable for good quality agriculture, silviculture, amenity horticulture and landscape sites supporting crops, grass, trees, shrubs and other herbaceous planting.

- General purpose grade topsoil may require improvement by lime and/or fertiliser treatment.

Economy grade

A5.4 This is derived from topsoil of lower quality than general purpose topsoil, or a material such as selected subsoil or friable mineral matter which is suitable for plant growth, such as river silt or glacial moraine. It is divided into materials of low clay (< 27% clay) and high clay (>27% clay) subgrades. The latter requires more careful handling and will be less tolerant of compaction. This material is suitable for amenity woodland, wildlife conservation areas, less intensively used amenity grassland and agricultural land of low inherent productivity.

- Because of its possible origin, no minimum organic matter or plant nutrient status is specified for economy grade topsoil and it may require fertilizing, manuring and careful husbandry for some uses.

A5.5 The Standard also recommends methods of soil sampling and analysis (see paragraph A2.6), as well as guidance on determination of soil texture and the use and handling of topsoil.

A6 Soil movement diagrams

A6.1 The sequence of soil movement operations using different equipment is illustrated in the following diagrams, Figures A.1 - A.5.

Table A.3 Determining characteristics of BS 3882 topsoil grades

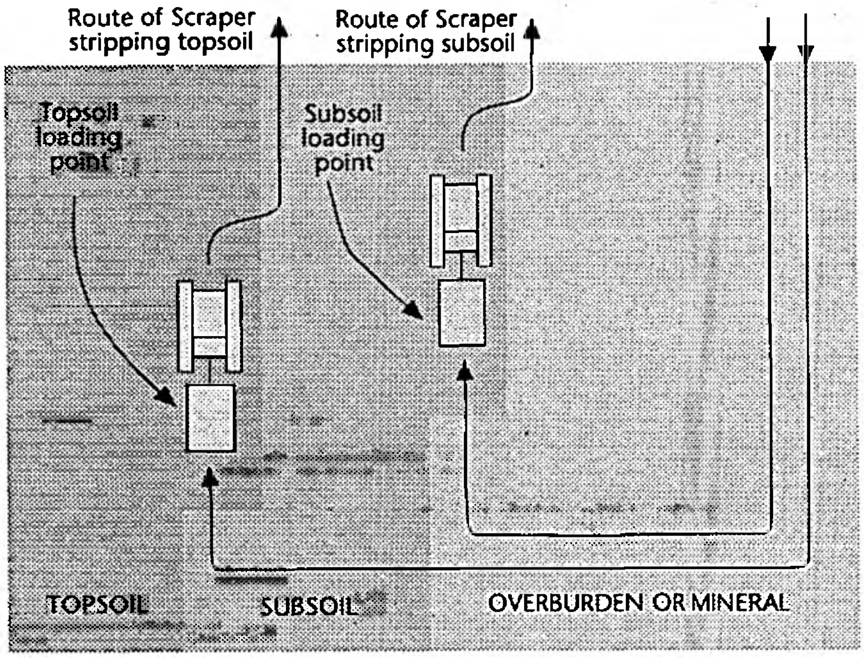
	Premium grade	General purpose grade	Economy grade	
			Low clay	High clay
Source		Origin to nearest 100m	-	-
Textural classification	Sandy clay loams, medium clay loams, medium silty clay loams, most loamy sands, most sandy silt loams, most silt loams	As premium grade but also including heavy clay loams, heavy silty clay loams, most sandy clays, most silty clays and some clays	As general purpose grade. Low clay to have <27% clay, high clay to have >27% clay)	
Maximum stone content (%) Stone size > 2mm >20mm >50mm	 30 10 0	 60 30 10	 65 60 40	
pH value	5.5 to 7.8	5.0 to 8.2	5.0 to 8.2	
Nutrient content P index min. K index min. Mg index min. N (%) min.	 2 2 1 0.2	 2 2 1 0.2	 N/A N/A N/A N/A	
Loss on ignition (%) (an approximation of organic matter content)	5 to 50 (for the specified textural classes)	depends on textural class and whether or not the soil is calcareous; the more clay the higher the required organic matter content. Minimum is 2 to 10%, maximum is 50%	Not specified	
Exchangeable sodium percentage (ESP) %	<10	<15	<15	

Description of operations

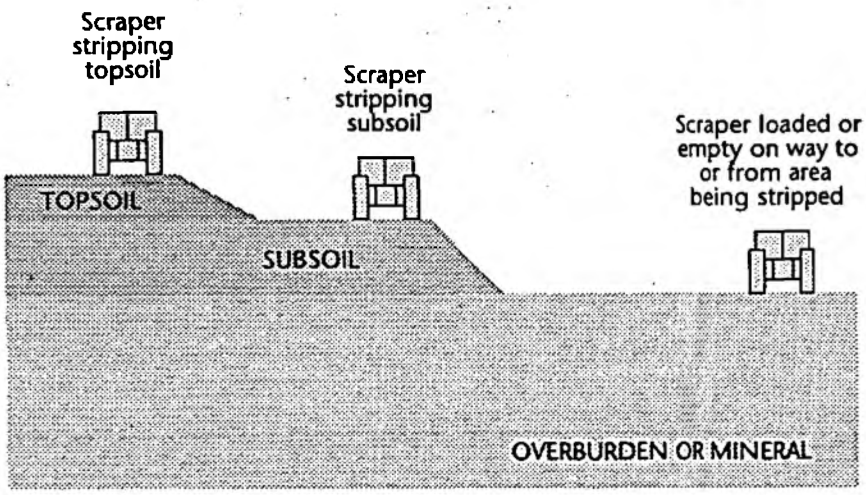
In topsoil stripping, the empty scraper runs across mineral or overburden, then briefly across subsoil to the topsoil stripping area. Immediately after loading it turns off into subsoil or mineral/overburden. In subsoil stripping, the empty scraper runs across mineral or overburden, then onto the subsoil stripping area. Immediately after loading it turns off onto mineral/overburden.

Figure A1 Stripping soil using an earthscraper (not to scale)

Plan



Schematic cross section

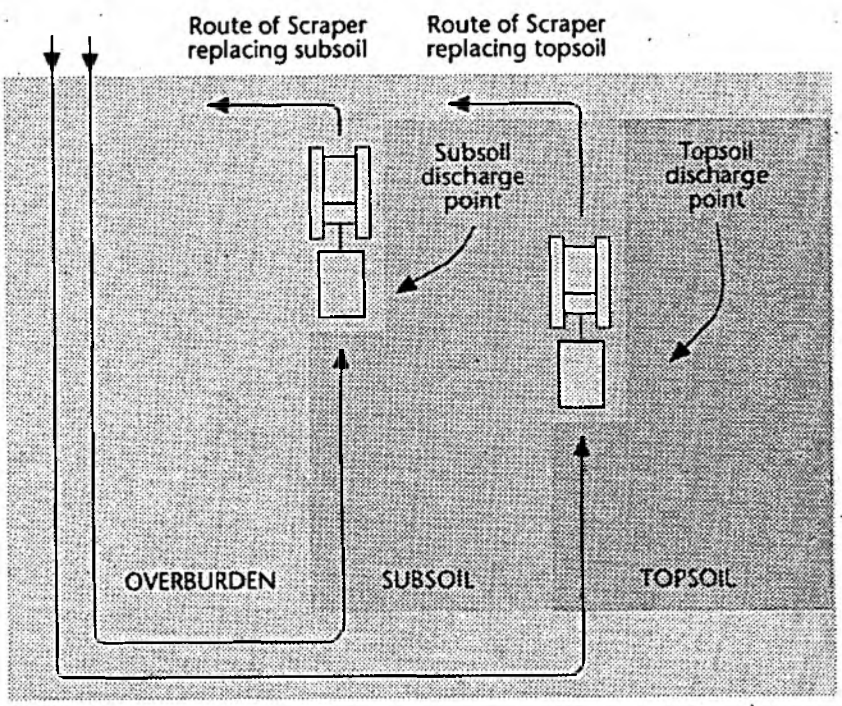


Description of operations

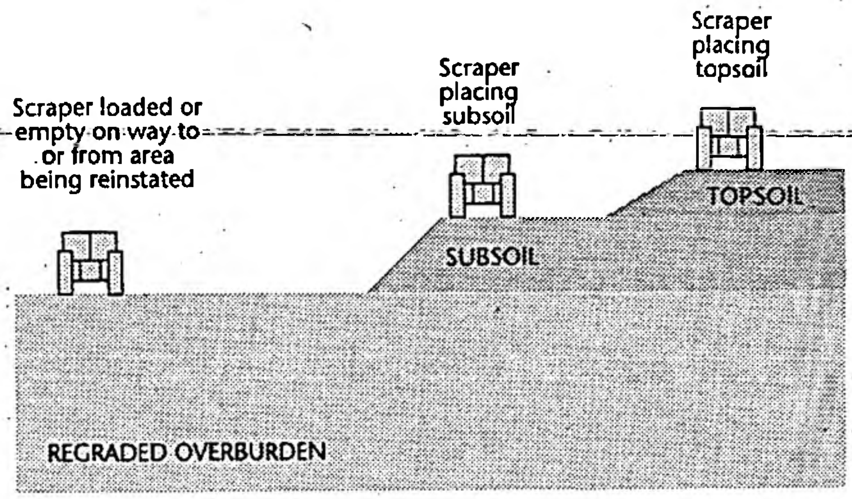
The overburden is graded to formation levels and "headlands" left at either end of the area being restored for machinery to arrive and depart running on overburden. The area would be restored in strips running upslope/downslope. The required thickness of subsoil would be placed in layers with the scrapers running downslope the entire length of the strip but in the same wheelings, discharging initially as near to the far end of the strip as feasible and with subsequent discharges progressively nearer the start of the strip.

Figure A2 Restoring soil using an earth scraper (not to scale)

Plan



Schematic cross section



Subsoil removal and reinstatement

Topsoil and subsoil is stripped in narrow bands across the area, the width of which will be determined by the jib length of the mechanical excavator used. All dump trucks run only on overburden or mineral, while the mechanical excavator stands on the soil horizon being stripped. The actual operation would consist of the excavator picking up the soil and loading into a dump truck before moving backwards along the bank being stripped to reach fresh soil.

Figure A3

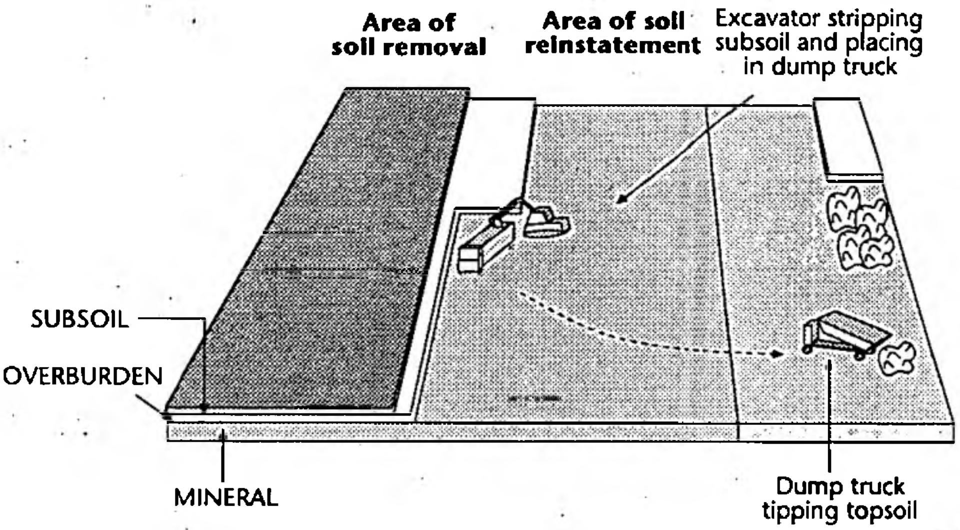
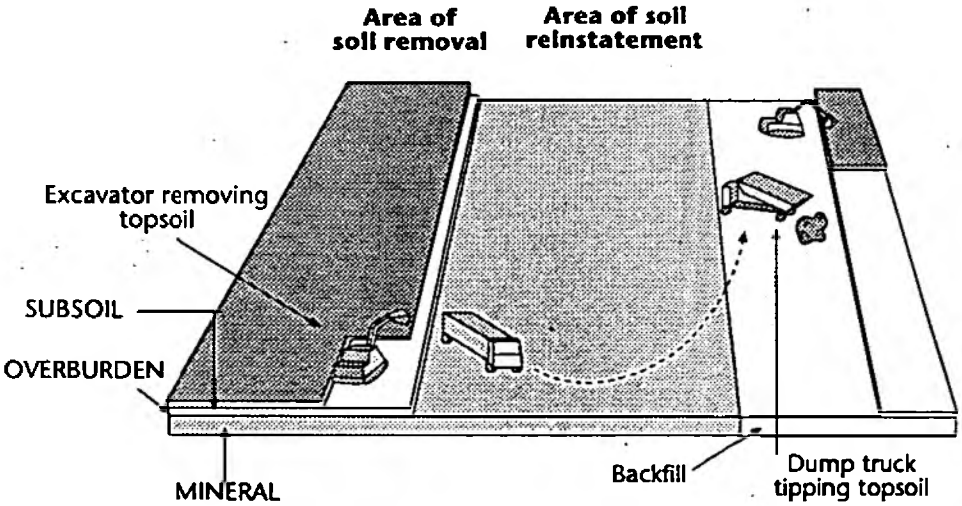


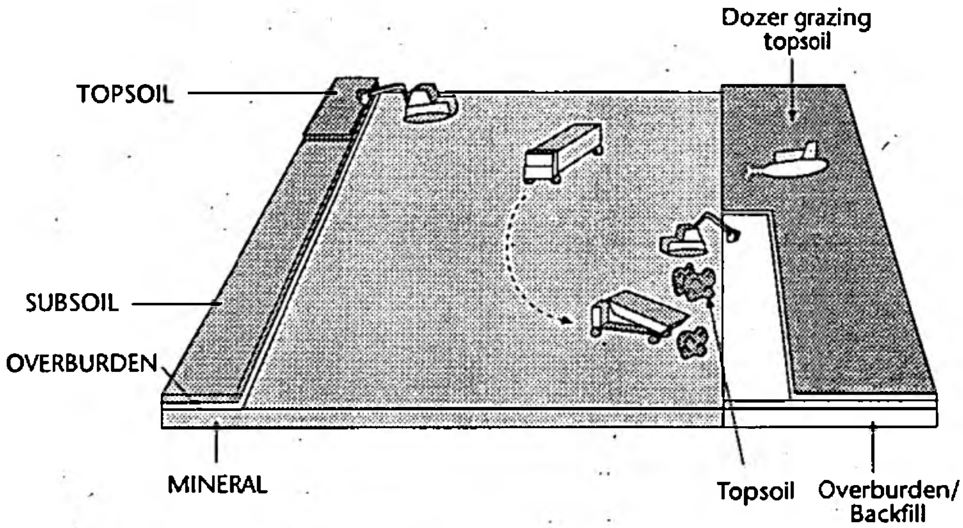
Figure A4 Topsoil removal and spreading



Completion of operations including grading of topsoil

The reinstatement of soils is also in bands across the area, the band width determined by the jib reach of the excavator in use. The subsoil is delivered by dump truck and the heaps graded out to the required thickness of subsoil by tracked dozer. Topsoil will then be delivered by dump truck and placed on and alongside the subsoil layer prior to final placement by mechanical excavator.

Figure A5



APPENDIX B

VEGETATION EFFECTS IN CONTROLLING RAIN WATER INFILTRATION

B1 It is essential to control rain water infiltration into the waste, to minimise the production of leachate so that the capacity of the leachate collection and disposal system is not exceeded. Studies carried out on behalf of the DOE by Keith Knox (Dec.1991) indicate that water balance methods can be used to predict leachate volumes and to design leachate management systems.

B2 Water balance calculations are based on the standard water budget equation, taking into account the rates of inflow and outflow. Inflow is primarily rainfall and any other liquid inputs, and outflow is made up of evapotranspiration losses and losses through run-off. Run-off includes both surface water run-off and lateral flow within the soil profile and drainage channels. Calculations must also take into account the absorptive capacity of the waste and the rate of landfill input.

B3 The study referred to in paragraph B1 also indicates the scepticism which exists concerning the use and reliability of water balance calculations in calculating potential leachate production.

- This seems to stem principally from the variations and inaccuracy of calculating the absorptive capacity of the waste and evapotranspiration losses.

The formulae commonly used to calculate the latter have been designed for agricultural applications to calculate irrigation requirements, and their direct application to landfill to calculate the losses from an active landfill system may lead to errors. The failure to quantify groundwater inputs (in unlined sites) may also lead to errors in calculating leachate volumes. The calculations are also very sensitive to variations in estimating actual rainfall, evapotranspiration losses from the waste and soil/vegetation systems, and hence the quantity of water available for downward percolation into the waste.

B4 It is however theoretically possible to achieve control of rainwater infiltration (and leachate production) on completed cells and phases of the landfill without developing a totally impermeable capping layer, by taking account of all influencing factors. The quantity and rate of rain water infiltration is the primary concern, and is controlled by

- seasonal rainfall
- cap and restored soil conditions
- gradient of slope
- vegetation - leading to evapotranspiration losses.

B5 The effect of seasonal rainfall and vegetation are closely correlated. On a vegetated site the vegetation will remove water from the soil during the summer in three ways.

- The leaves of the plant will intercept rainfall and prevent it from reaching the soil; this water will be lost by evaporation.
- The plant will take water out of the soil through the roots for growth. This water will subsequently be lost through the leaves by transpiration.
- Water which has drained through the upper layers of the soil into the ground water supply, or into the subsoil reservoir will be used by the plants when necessary and also lost by transpiration.

B6 The vegetation effect is most marked during the summer when the plant is growing actively, and has the greatest requirement for moisture. For most of the British Isles this results in the development of conditions of Soil Moisture Deficit which last from April until October. When this condition exists, there is

- ► insufficient moisture in the soil for optimum plant growth
- ► very little movement of water within the soil profile
- ► rain water which enters the soil system being taken up by the plants.

The effect of Soil Moisture Deficit on evapotranspiration and hence downward percolation of rain water is very important.

B7 Conditions of Soil Moisture Deficit fluctuate during the summer. Models used by the Met. Office in predicting the behaviour of moisture in the soil generally assume that moisture will not pass down the soil profile until the Soil Moisture Deficit is reduced to zero, and the soil is at or above Field Capacity.

- In practice it has been found that there is minimal infiltration even at significant moisture deficits, and percolation will be more rapid along cracks in the soil profile.

Heavy summer rainfall may lead to a rapid infiltration rate along soil cracks even under extreme conditions of Soil Moisture Deficit.

B8 With the onset of winter, the evapotranspiration effect reduces and finally stops. The rain which then falls gradually soaks the soil, but until the soil reaches Field Capacity there is no general downward movement of water through the soil profile. When Field Capacity is reached, the upper layers of soil will become saturated and water will move down the soil profile on a wetting front. This continues throughout the winter until the following spring when evapotranspiration losses exceed rainfall, and conditions of Soil Moisture Deficit are reached, commencing in the surface layers of soil. The amount of rainfall in the winter which is surplus to the plant requirements, and therefore available for downward percolation, is termed Excess Winter Rainfall.

B9 The water balance calculation cannot be applied simplistically without a full understanding of all the inherent variable factors.

- The formulae for predicting soil moisture deficits and evapotranspiration losses are generally reliable in predicting losses from vegetated surfaces, as they were designed for crop irrigation use, providing accurate site meteorological and crop data are available, but soil factors may lead to errors.

In summer actual evapotranspiration may be less than the potential because the soil holds onto its moisture much harder as it dries out. Heavy rainstorms in dry periods may lead to rapid recharging of the moisture levels in the soil.

B10 Agro-climatic data (available from the Soil Survey and Land Research Centre) may be used for the calculations. Figures for Excess Winter Rainfall, and the start and end of Field Capacity for land under different crops, including grass, may be obtained with a fair degree of accuracy for sites throughout the country. The reliability of the calculations would be increased by obtaining actual site rainfall figures, using a rain gauge on site.

B11 The same organisation also holds measured field data on hydraulic conductivity, both lateral and vertical, for different soil types. This information may be used to predict the rate of infiltration of water through the soil profile. For a given depth of soil, of a known type, it is therefore possible to calculate how far down the wetting front will move before conditions of Soil Moisture Deficit return, and thus the minimum soil depth for controlled infiltration. The depth may be designed to allow water into the waste for a given period or not at all.

B12 It is commonly recognised that one of the main impediments to successful restoration of derelict or despoiled land is the soil compaction which almost inevitably results when soils are disturbed, stacked and spread. Soil compaction reduces the permeability of the soil, and it is therefore common to have relatively impermeable conditions on newly restored sites. Surface waterlogging is much more prevalent than rapid drainage. On sloping ground this will lead to surface water run off and water flow through the upper, permeable soil layers.

B13 The effect of slope gradient must also be taken into account in the calculation. Gradients which encourage surface water run off will take longer to reach saturation in the upper layers, and this will delay the downward movement of water. The data held by the Soil Survey and Land Research Centre indicates that a slope of 1 in 5 may take 1 to 2 weeks longer to reach saturation at 50cm. depth than a slope of 1 in 30.

B14 Using the above information, local agro-climatic data, and a knowledge of the site contours and soil types available for use on the site, it is possible to design a capping system which takes all the influencing factors into account. This system could have minimal permeability without the necessity of importing and compacting large quantities of clay which comply with a very strict specification. The capping system will also be capable of being designed to allow some water into the waste over the whole surface area of the site to promote biodegradation and waste stabilisation.

B15 Using this system it is possible to predict the depth of capping layer required to

- prevent water from entering the landfill
- allow water to enter the landfill for a given period of time
- calculate, using rainfall and soil data, the quantity of water entering the landfill for that given period.

The calculation inevitably relies upon some theoretical data - predicted soil conditions, albeit based upon experience in the field, and the most appropriate available meteorological data, (which may not equate exactly to site conditions), and therefore it is recommended that the calculations be verified in site with field trials.

APPENDIX C

LIST OF PLANNING POLICY AND MINERAL PLANNING GUIDANCE NOTES

* Guidance extends to England only, not to Wales.

Those shown bold may be of particular relevance for landfill restoration

PPG1	***General Policy and Principles (1992)***
****PPG2***	***Green Belts (1988)***
*PPG3	Housing (1992)
PPG3 (Wales)	Land for Housing in Wales (1992)
PPG4	Industrial & Commercial Development and Small Firms (1992)
PPG5	Simplified Planning Zones (1992)
PPG6	Town Centres and Retail Developments (1993)
PPG7	***The Countryside and the Rural Economy (1992)***
PPG8	Telecommunications (1992)
****PPG9***	***Nature Conservation (1994)***
*PPG10	Strategic Guidance for the West Midlands (1988)
*PPG11	Strategic Guidance for Merseyside (1988)
*PPG12	Development Plans and Regional Planning Guidance (1992)
PPG12 (Wales)	Development Plans in Wales (1992)
*PPG13	Transport (1994)
PPG14	***Development on Unstable Land (1990)***
*PPG15	Planning and the Historic Environment (1994)
PPG16	***Archaeology and Planning (1990)***
PPG17	Sport and Recreation (1991)
PPG18	Enforcing Planning Control (1992)
PPG19	Outdoor Advertisement Control (1992)
PPG20	Coastal Planning (1992)
PPG21	Tourism (1992)
PPG22	Renewable Energy (1993)
****PPG23***	***Planning and Pollution Control (1994)***
****PPG24***	***Planning and Noise (1994)***

APPENDIX C

Minerals policy guidance notes

MPG7 may be of particular relevance for landfill restoration

MPG1	General Considerations and the Development Plan System (1988).
MPG2	Applications, Permissions and Conditions (1988).
MPG3	Coal Mining and Colliery Spoil Disposal (1994). (Superseding Opencast Coal Mining (1988).
MPG4	The Review of Mineral Working Sites (1988).
MPG5	Minerals Planning and the General Development Order (1988).
MPG6	Guidelines for Aggregates Provision in England (2nd ed. 1994).
MPG7	*The Reclamation of Mineral Workings (1989).*
MPG8	Planning and Compensation Act 1991: Interim Development Order Permissions (IDOs) - Statutory Provisions and Procedures (1991).
MPG9	Planning and Compensation Act 1991: Interim Development Order Permissions (IDOs) - Conditions (1992).
MPG10	Provision of Raw Material for the Cement Industry (1991).
MPG11	The Control of Noise at Surface Mineral Workings (1993).
MPG12	Treatment of Disused Mine Openings and Availability of Information on Mined Ground (1994).

APPENDIX D

COMPUTER AIDED DESIGN SOFTWARE

This appendix describes some commonly-used CAD software, and should not be construed as an endorsement or recommendation of any system.

D1 MOSS software for waste management

D1.1 MOSS Systems produce a range of software which operates on PC's in a windows environment and also on UNIX based workstations. The software is modular, can be tailored for specific needs, and can create and handle large and complex projects with many layers.

D1.2 Within the waste management field it provides, if required, a total solution from data input through design and analysis, measurement, drawings (plan, sections, perspectives), visualisation and visual impact analysis.

D1.3 In more detail:

			Software Package
1.	Data input :	Land survey	MOSS or TopoMOSS
		Aerial survey	MOSS or TopoMOSS
		Geological data	MOSS or Strata 3
		Ordnance survey Digital data	Ordnance Survey pre-processor
2.	Landfill design including:	Cap Liner	MOSS
		Leachate wells	MOSS
		Monitoring wells	MOSS
		Cell design	MOSS
		Access roads	MOSS
		Screening mounds	MOSS
		Landform design	MOSS
3.	Surface analysis:	Triangulation Contours	MOSS and TopoMOSS
4.	Area & volumetric assessment using section and/or provided volumes:	For all of the designed items above.	MOSS and TopoMOSS
5.	Visual analysis:	Wireline perspectives	MOSS
		Photomontage	MOSS
		Photorealistic recorded images	EPIC
		Photorealistic animations	MOSS

6.	Drawings to contract standard:	Plans Long sections Cross sections	MOSS MOSS MOSS
7.	Visual impact analysis:	Single and multiple eye points	Specifically tailored programme

Available from: Moss Systems Limited
Moss House
North Heath Lane
Horsham
West Sussex RE12 5QE

Telephone No. 01403 25951

D2 AUTOCAD third party add-on software packages

D2.1 *Key system*

Key systems comprises a suite of software packages developed in the UK which are third party "add ons" to software for AutoCAD.

Keyscape	Landscape planning and design for softworks and hardworks
Key DGM	Groundmodelling/volume calculations and visual analysis
Key Terrafirma	Site design and road layouts
Key Planning	A mini geographical information system
Keyscape Estimator	Estimating package

Available from: Key Systems
Systems House
Burnt Meadow Road
Moons Park
Redditch B98 9PA

Tel: 01527 68888

D2.2 LandCADD

LandCADD is an American software package for use as an add on to AutoCAD.

LandCADD	The basic package for landscape design and graphic presentation.
Quadrangle	Groundmodelling and visual analysis is due to be replaced by Eaglepoint.
Earthworks	Volume calculation.

One of the main distributors:

AI Systems
Peel House
Peel Road
West Pimbo
Skelmersdale
Lancashire WN8 9PT

D3 Land survey system (LSS)

D3.1 LSS is a general purpose land surveying and terrain modelling package used by land surveyors/engineers for a wide range of tasks, including quarrying, road building, waste management, surveying road and air accidents and landscaping.

D3.2 Within waste management, LSS is used for

- land surveying - recording original ground levels, interim ground levels, etc.
- designing proposed surfaces - finished levels, cells, bunds, etc.
- volume calculations between any pair of models, ie surfaces representing the terrain at any stage of development
- settlement calculations
- creation of 3-D views from any viewpoint
- studies of the visual impact of a site on the surrounding countryside.

D3.3 LSS is available from:

McCarthy Taylor Systems Ltd
Acorn House
Shab Hill
Birdlip
Gloucester GL4 8JX

Tel: 01452 864244
Fax: 01452 864194

APPENDIX E

LANDFILL GAS SYSTEMS AND RESTORATION

E1 Components of the gas control system

E1.1 The main components of gas control and utilisation systems are briefly described in the following paragraphs so that restoration design decisions may be made with a fuller understanding of the features, requirements and constraints of the gas system.

E1.2 The design of the landfill gas system will depend upon the gas production rate, which is affected by the types of wastes which the site has accepted and the age of the site. Restoration and landscape design approaches and solutions will be influenced by the design requirements of the gas system.

i *Migration monitoring boreholes*

E1.3 Sites which have accepted biodegradable wastes, namely household waste sites, commercial and industrial waste sites and sites which have taken demolition wastes will produce landfill gas during biodegradation of the wastes. These sites will require systems to monitor whether landfill gas is migrating out of the site (migration monitoring systems), and the installation of some form of landfill gas control or extraction system should be planned at the outset.

E1.4 Gas migration monitoring systems comprise boreholes sunk at intervals of 30 to 50 metres (on some sites very much closer) around the perimeter of the landfilled area. These boreholes are suitably located outside the filled area. Their purpose is to identify whether landfill gas is escaping from the site and to demonstrate the performance of the gas control system. On older sites detection of gas in these perimeter monitoring boreholes will trigger the installation of a gas control system or the extension of an existing system if necessary.

E1.5 The monitoring boreholes are terminated in a visible small cap or metal box just above the ground. This borehole head arrangement will usually be set in a small concrete surround.

E1.6 Monitoring can be carried out either manually with portable instruments and/or datalogger, or with in situ analyser/dataloggers or a combination of both.

- Datalogged information may be transmitted via PSTN telemetry equipment automatically as part of SCADA or manually interrogated via PC and modem.

In either case software is available to store, graph and display the accumulated historical site readings as necessary. If in situ analysers are installed, telemetry cables (fibre optics) will be laid in the ground between each monitoring borehole linked to the outstation PC, usually located in the gas compound. The analyser equipment will be housed in a small metal chamber over each monitoring borehole; this will be bigger than a borehole cap without instrumentation.

ii *Passive gas vents*

E1.7 On old, closed landfill sites the control system may comprise a number of passive gas vents. This system may also be adequate on small sites which have accepted mostly non-biodegradable wastes, shallow sites and those which were licensed to take demolition wastes. Vertical passive vents are usually 1.5 -2 m high but may extend up to 4 metres above ground level, and may or may not be linked together below ground by horizontal pipes.

E1.8 Passive vent trenches may also be installed to prevent lateral migration to a particular, isolated area. These are excavated to the full depth of the waste, usually lined on the outer wall with an impermeable membrane and backfilled with permeable fill. The trench may be filled to the surface to allow direct venting to atmosphere, or the permeable fill may be covered with a layer of soil. In this latter case a perforated pipe will run in the top of the permeable fill, connecting a series of vertical venting columns set at intervals along the trench.

E1.9 Passive gas venting is not generally considered to be a satisfactory control system for the majority of modern landfill sites with high proportions of biodegradable wastes.

iii *Active extraction systems*

E1.10 The recommended gas control system on modern landfill sites which have accepted biodegradable wastes is an active extraction system. This comprises an arrangement of vertical gas wells connected below ground via horizontal pipes which lead to a gas compound. The gas is delivered to either a flare stack or gas utilisation equipment, or both. Depending upon the design of the system, the wells may be linked together, commonly in a regular grid pattern across the site, or they may be linked separately or in series to a gas main which runs around the perimeter of the site or phase. The pipework is usually placed either just below, or preferably just above the capping layer to facilitate repairs.

- **The depth of the gas collection pipework must be deep enough so as not to compromise aftercare operations such as drainage and deep cultivations.**

E1.11 The vertical wells and their associated valves and monitoring gear usually terminate at or above ground level in an inspection chamber. If the chamber is within the soil layers, there will be a manhole lid and concrete surround at or just above the ground. The gas wells may be very frequent, depending upon site requirements, with 25 to 50 metre centres on a regular grid pattern being common.

E1.12 Gas migration control systems and gas utilisation systems can have different suction requirements.

- *Gas migration control* relies upon a strong suction from more closely spaced (20 to 40 m) wells with a reasonable degree of overlap in their sphere of influence. The quality of the gas in terms of methane proportion is not a priority.

- Wells for *gas utilisation* will usually be more widely spaced (40 to 80 m), with the suction controlled to give gas of the right quality for the utilisation equipment (about 40% methane).

Different parts of the site may therefore have gas wells at different spacings. The location of migration control wells around the edge of the site will be strongly influenced by site safety needs, whereas the spacing and location of gas utilisation wells in the body of the site may be more flexible.

E1.13 Remote monitoring and datalogging via telemetry links are also available for active gas extraction systems, and require below-ground connection to the outstation, located in the gas compound.

iv Landfill gas compound

E1.14 The landfill gas compound will contain, in addition to the flare stack, pumping equipment and dewatering points to remove condensate. If the gas is being used to produce energy the compound will also house the gas engines or turbines, electricity generating equipment and transformers, and control equipment. Operational requirements for the gas compound include

- need for easy access for vehicles and machinery,
- provision of electrical power, water and telephone services,
- easy access for maintenance of equipment,
- suitable for the export of electricity or gas as an energy source.

E2 Installation of the system

E2.1 The landfill gas control system, or part of it, may be partially in place before landfilling is commenced, and certainly before the site is completed and capped. During the operational phase of the site gas control may be effected through the use of temporary wells, pipework and flares.

E2.2 The permanent landfill gas control system will usually be installed on the completion of landfilling in any phase, and is therefore in place before settlement has taken place. It has been reported that settlement is more rapid when active gas extraction is being undertaken. This is likely to result in disturbance to the gas control system. Pipework may settle over some lengths and these low sections will be subject to potential blockage by condensate so that they no longer transport the gas efficiently. The vertical wells may deform and the pipework connections into the wells may distort or fracture.

E2.3 On older sites the active extraction system may be installed on part of the site only, in response to gas migration. Such a system may well require extending as the site is completed or as later areas of landfilling begin to produce gas. On completed sites where a passive system has been previously installed, it may prove necessary to convert this system to an active extraction system.

E3 Design of the gas system

E3.1 Consideration should be given wherever possible to

- **siting monitoring boreholes and gas wells in areas which will not be intensively managed, along farm access tracks, field headlands, woodland rides or firebreaks.**

- **placing the pipework below the depth of future drainage and cultivations.**

E3.2 A number of gas control systems are available, which differ in their design features and general arrangements. One system may be more suited to the site than another.

- **The choice of system should be made with the proposed after-use in mind, to minimise the disturbance caused by the system during aftercare.**

Consideration may be given to separating the vertical well from its associated control gear and monitoring equipment. This will allow placement of wells where they are needed in sensitive areas for gas extraction and site safety, while locating the surface or above surface features in more suitable and practical areas remote from the well. The vertical well should extend above the capping layer into the lowest layers of the soils in these cases with the gas pipe located likewise.

E3.3 The location of the gas mains should preferably be in ground which is least likely to suffer the effects of settlement, either in undisturbed areas or located in the oldest (i.e. maximum post settlement) areas of landfill. The choice of gas collection main type - ring main, radial main or manifold system will be site specific in order to achieve the objectives of

- minimal settlement of the mains
- provision of adequate falls
- providing adequate suction to the various points of gas extraction
- following established permanent access routes for easy maintenance and to provide a convenient siting for the control/monitoring equipment associated with remote gas wells.

This approach can provide the operator with the security of knowing that the gas mains will be permanent and reliable features subject to the least degree of settlement and disturbance.

E3.4 The branch mains that lead to individual wells or groups of wells will be most likely to require maintenance, but failure of minor sections is more easily rectified and less likely to result in loss of migration control or loss of energy production. Localised repairs will be less damaging to restored areas as reinstatement can be confined to specific areas.

APPENDIX F

HEALTH AND SAFETY

F1 Construction (Design and Management) Regulations 1994: health and safety plan

F1.1 The Health and Safety Plan prepared under Regulation 15 (1) - (3) should include the following information:

1 Nature of the project

- Name of client
- Location
- Nature of construction work to be carried out
- Timescale for completion of the construction work

2 The existing environment

- Surrounding land uses and related restrictions, eg premises (schools, shops or factories) adjacent to proposed construction site, planning restrictions which might affect health and safety.
- Existing services, eg underground and overhead lines.
- Existing traffic systems and restrictions, eg access for fire appliances, times of delivery, ease of delivery and parking.
- Existing structures, eg special health problems from materials in existing structures which are being demolished or refurbished, any fragile materials which require special safety precautions or instability problems.
- Ground conditions, eg contamination, gross instability, possible subsidence, old mine workings or underground obstructions.

3 Existing drawings

- Available drawings of structure(s) to be demolished or incorporated in the proposed structure(s) (this may include a health and safety file prepared for the structure(s) and held by the client).

4 The design

- Significant hazards or work sequences identified by designers which cannot be avoided or designed out and, where appropriate, a broad indication of the precautions assumed for dealing with them.
- The principles of the structural design and any precautions that might be needed or sequences of assembly that need to be followed during construction.

- Detailed reference to specific problems where contractors will be required to explain their proposals for managing these problems.

5 **Construction materials**

- Health hazards arising from construction materials where particular precautions are required either because of their nature or the manner of their intended use. These will have been identified by designers as hazards which cannot be avoided or designed out. They should be specified as far as is necessary to ensure reliable performance by a competent contractor who may be assumed to know the precautionary information that suppliers are, by law, required to provide.

F2 Safety audit

F2.1 It will be advisable to carry out a safety audit to identify and record the relevant information and emergency procedures under the following headings:

Fire hazard - precautions, access to emergency services

Electrical safety

Gas regulations - monitors in enclosed spaces (pump room, gas engines etc.)

Explosion relief system

Permits to work

Confined space working

Lagoon security.

APPENDIX G

AFTERCARE PROGRAMME

Introduction

Mineral Planning Guidance Note 7 suggests that an aftercare scheme should consist of:

- an **outline strategy** of commitments for the 5 year aftercare period
- a **detailed programme** for the forthcoming farming year, to be submitted in sufficient time for it to be agreed before implementation.

Regular aftercare meetings should also be held to review progress to date, and to discuss and agree future operations.

Examples are given on the following pages of a typical outline stategy, a detailed programme for the initial year of aftercare, and a dossier for a full 5 year aftercare programme. These are taken from *The Restoration of Mineral Workings to Agriculture*, RPS and Wye College, 1996.

Outline Strategy

Crabtree Farm Quarry, Cottertown, Loamshire - Aftercare

An Outline Strategy for the restored land at Crabtree Farm Quarry, Cottertown, Loamshire is set out below, in compliance with Conditions 43 and 44 of the Planning Permission dated 19/5/1985 (Reference SGM/MB/JT/821/85). This outline strategy will apply to each of the restoration phases as they enter the aftercare stage.

1 The proposed cropping pattern is to be grass for the first two years, followed by an arable crop (probably winter cereals or oilseed rape). This arable crop will be followed by further arable crops or a return to grassland if site conditions are such that this would be a better course of action.

2 The intention is to sow initially a medium term grass ley to be cut for hay or silage. Depending on ground conditions the land may be grazed with sheep or cattle after the grass has become well established.

3 The cultivations carried out for the initial grass will those which are necessary to produce a suitable seed bed for the sowing of grass, given the soil conditions prevailing at the time. Care will be taken not to overcultivate, so that it is likely that the initial cultivations will consist simply of ploughing, one or two harrowings, and rolling after seeding.

4 Soil samples will be taken so that appropriate lime and fertiliser base dressing will be applied as necessary for the establishment of the initial grass. Further fertiliser dressings, e.g. spring topdressing with nitrogen, will be carried out as necessary. Further soil analyses will be carried out as required (e.g. at the start of arable cropping).

5 Such other operations as are found to be necessary, such as spraying to control weed growth, will be carried out.

6 The company will undertake to carry out such remedial treatments as may be necessary to return the soil to its original physical characteristics. For example, if the topsoils have become any stonier than comparable adjacent undisturbed land, then appropriate stone-picking operations will be carried out.

7 The company will also undertake to install drainage and/or carry out subsoiling operations if these are found to be necessary during the aftercare period.

8 It is proposed that annual aftercare meetings be held to review progress, and specifically to receive cropping and husbandry information for the preceding year, to agree the cropping proposals for the forthcoming year, and to discuss and agree on any other relevant matter, such as those mentioned in paragraphs 6 and 7 above.

Detailed Programme for Phase A of Restoration, 1st Year of Aftercare (1988-89)

Note that this is effectively a specification for only a single year of cropping within a five year aftercare programme

SITE	Crabtree Farm Quarry, Cottertown, Loamshire (phase A). Soil replacement completed in June 1988.
AREA	9 ha (22 acres).
CROPPING YR.	1988/89 (Initial Aftercare Crop).
CROP	Medium term ryegrass ley.
CULTIVATIONS	Normal cultivations to provide a sufficiently fine seed bed for grass. To be rolled after seeding.
SOIL ANALYSIS	(Carried out on samples collected 6th. July 1988).

pH	Lime Requirement	N Index	P205 Index	K20 Index	MgO Index
7.3	Nil	0	2	2	2

LIMING	None required (calcareous soil)

Proposed Base Fertliser Applications

Assuming a spring sown grass, 200 kg/ha of 0:24:24 compound fertiliser, to supply 0 kg N, 48 kg P205, and 48 kg K20 per hectare should be applied. This should be followed by a topdressing of nitrogen.

Other Treatments Proposed or Already Carried Out

Clearance of volunteer weeds (mainly mayweed and bristly ox-tongue) was carried out on 20th. July 1988 using Roundup. Attention to weed control will be necessary during establishment of grass and especially in spring of 1989. Control may be possible by cutting, but herbicide treatment is more likely to be required. The specific treatment will depend on the range of weed seedlings which appear.

Underdrainage is due to be installed during September 19898 accompanied by moling.

Record of Operations carried out on Phase A of Restoration, 1st Year of Aftercare (1988-89)

1 Clearance of volunteer weeds (mainly mayweed and bristly ox-tongue) was carried out on 20th. July 1988 using glyphosate (Roundup).

2 Underdrainage was installed in September 1988, and moling carried out across the drainage lines. The land was then ploughed and left bare over winter.

3 In the 2nd. week of March 1989 the land was lightly cultivated (harrowed once), and seeded with 35 kg/ha of a medium term ryegrass ley (17.5% Fenema, 32.5% Fantoom, 32.5% Tivoli and 17.5% Port Stewart). A fertiliser dressing of 200 kg/ ha of 0:24:24 compound fertiliser was applied at the time of seeding, supplying 0 kg N, 48 kg P205, and 48 kg K20 per hectare. After seeding the land was rolled twice.

4 After emergence, a topdressing of 110 kg/ha N was applied in the form of ammonium nitrate (34.5%N), applied at a rate of 320 kg/ha.

5 A broad-leaved herbicide containing Mecoprop (Herrifex DS) was applied on May 15th 1989.

6 The grass was mown in August 1989 and a haycrop taken. This was followed by an application of 85 kg/ha N in the form of ammonium nitrate (34.5%N), applied at a rate of 250 kg/ha on 20th August. The regrowth was good, and 150 lambs were turned out onto the field in early September, remaining there until taken off in the second week of November 1989.

7 A site inspection made on 19th November 1989 found that the growth of grass on Phase A was not quite as good as on adjacent unworked land, and the topsoil was slightly more stony. However topsoil structure was similar on both the restored land and on the adjacent unworked land, and no perched water was found within the reinstated profile.

Proposals for Phase A of Restoration, 2nd Year of Aftercare (1989-90)

1 It is proposed to continue the grass ley for a further season, and to take two or possibly three cuts of silage in 1990, grazing the aftermath probably with heifer calves or sheep.

2 It is proposed to apply a topdressing of 0:24:24 compound fertiliser to supply 60 kg P205, and 60 kg K20 per hectare in February 1990.

3 For the first silage cut a topdressing of 100 kg/ha N is proposed, for the second cut 75 kg/ha N and 50 kg/ha K20 (as Kaynitro or similar). and if a third cut is envisaged, a further 60 kg/ha N and 40 kg/ha K20 (as Kaynitro or similar).

4 Weed control by herbicide spray will be carried out as necessary.

Aftercare Dossier, Phase A (1988-93)

SITE Crabtree Farm Quarry, Cottertown.

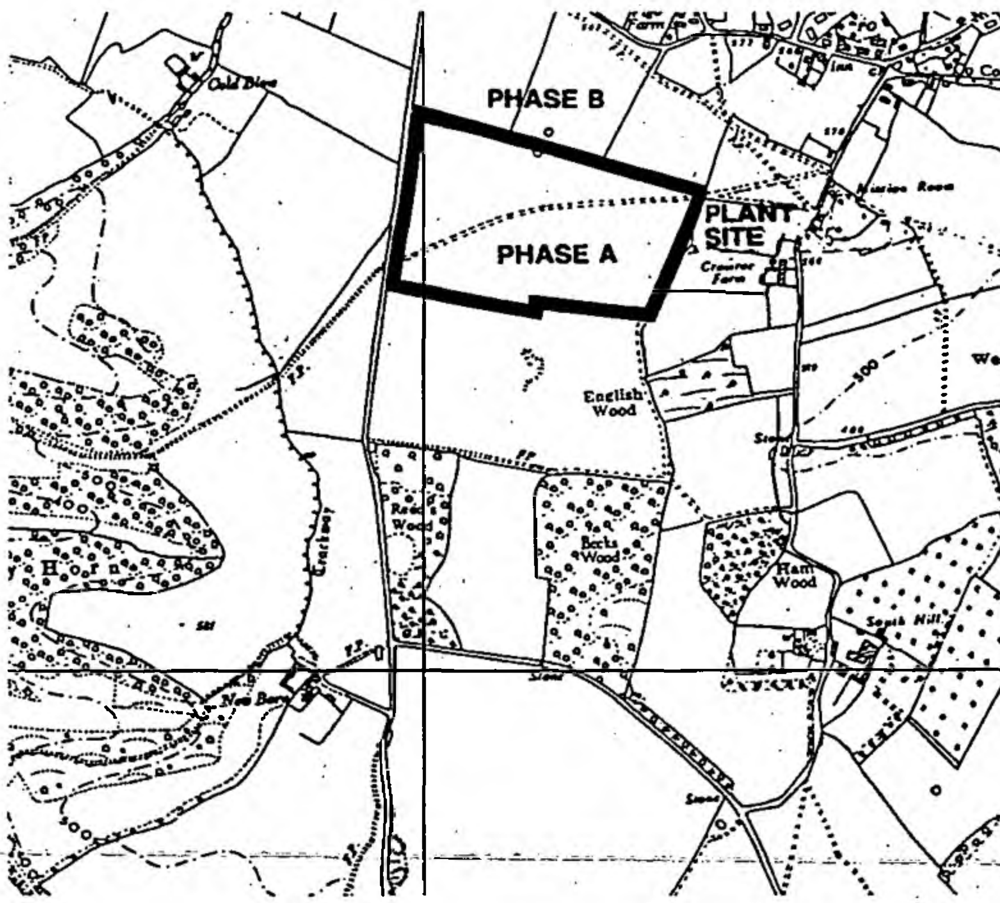
OPERATORS REF. SE76/233.

MPA REF. SGM/MB/JT/821/85).

MAFF REF. CD/1022B.

CONTENTS Summary Sheet (including site details).
Drainage Operations.
Cropping Records.
Pesticides Glossary.

Location Plan



Summary Sheet

SITE	Crabtree Farm Quarry, Cottertown, Loamshire (Phase A).
AREA	Approx. 9 ha (22 acres) on the south west corner of the site, bounded to the east by the processing plant, to the south and west by unworked land, and to the north by Phase B of the workings.
FARMER	Mr P Adam, Brook Farm, Cottertown, Loamshire. Tel. 01233 812258.
REINSTATEMENT	1987-8 over backfilling with overburden and quarry wastes. Soil replacement completed in June 1988.

DRAINAGE (PRIMARY & SECONDARY TREATMENTS)

1988 (September)	Piped underdrainage installed.
1988 (September)	Moled.
1990 (August)	Subsoiled.
1991 (July)	Subsoiled.

CROPPING

Year	Crop	Yield
1988-89 (Year 1)	Grass	Hay crop then grazed.
1989-90 (Year 2	Grass (continuation)	Two cuts of silage, then grazed.
1990-91 (Year 3)	Winter wheat	3.7 tonnes/ha.
1991-92 (Year 4)	Winter barley	5.6 tonnes/ ha.
1992-93 (Year 5)	Oilseed rape	2.6 tonnes/ha.

Drainage Operations

SITE Crabtree Farm Quarry, Cottertown, Loamshire (Phase A)

OPERATIONS

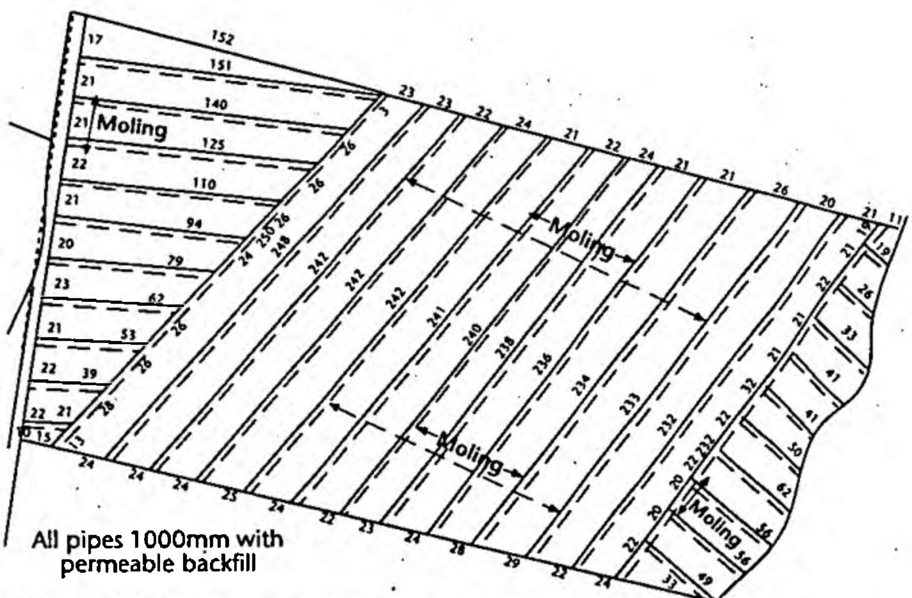
1 Piped underdrainage installed in September 1988 (see accompanying drainage plan).

2 Moled across the drainage lines using a D7 pulling a mole at 55 cm depth and 2.7 m spacing in damp but firm conditions in September 1988 following underdrainage installation.

3 Subsoiled with 4WD tractor and multi-tine at 35 cm depth and 38 cm spacing in August 1990.

4 Underdrainage installed on adjacent restored land (Phase B) in July 1991, to provide comprehensive system for this corner of the site.

5 Subsoiled with 4WD tractor and multi-tine at 35 cm depth and 38 cm spacing in July 1991 in conjunction with Phase B.



APPENDIX H

THE WOODLAND GRANT SCHEME

H1 The Forestry Commission's Woodland Grant Scheme (WGS) was introduced in 1988. Its aims are:

- to encourage people to create new forests and woodlands to
  - increase the production of wood
  - improve the landscape
  - provide new habitats for wildlife
  - offer opportunities for recreation and sport.
- to encourage good management of forests and woodlands,
- to provide jobs and improve the economy of rural areas,
- to provide a use for land instead of agriculture.

H2 All woodland, including coppice and short rotation coppice, is eligible for consideration for grants under the scheme. Normal threshold qualifications for the WGS are that areas designated for woodland should not be less than 0.25 ha in size or less than 15 m in width.

H3 There are two groups of grants available:

- planting grant which is designed to assist planting
- annual management grant which helps with the subsequent maintenance of woodland.

H4 Application forms can be obtained from, and should be returned to, the local Forestry Authority office. The application should describe

- the type of woodland proposed
- the long-term objectives of the woodland
- work proposed during the initial 5 year establishment period to meet these objectives.

A map of the proposed planting area is required, which for small areas should be on a scale of 1:2500. After examination of the proposal and a visit to the site, the proposal will either be accepted, modified or rejected. Once the proposals are acceptable, a contract is signed under which the owner undertakes to manage the woodland to an agreed standard throughout the grant period.

H5 Landfill sites which were restored to an agricultural after-use (arable or grassland) may be eligible for a Better Land Supplement if a change of land use to woodland is proposed. Eligibility is explained in a leaflet obtainable from Forestry Authority Offices.

H6 A Community Woodland Supplement is also available under the Woodland Grant Scheme, subject to certain conditions being met. To be eligible, proposals must be within 5 miles of the edge of a village, town or city, and in an area where the opportunities for woodland recreation are limited. In addition, it is a condition of the supplement that there should be free public access. Woodland established with the support of the supplement will also be eligible for annual management grant from age 11 onwards.

H7 Annual management grants are available to assist the woodland maintenance and improvement once trees are 5 years old. Such plans are expected to safeguard or increase the environmental value of the woodland or create, maintain or enhance public access.

H8 A Woodland Grant Scheme Applicants Pack, which includes information about the grant and a brief guide to conserving and improving the forest environment, is available from The Forestry Authority, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, GU10 4LH or the Woodland Officer at the Forestry Authority regional offices.

APPENDIX J

SOURCES OF INFORMATION AND ADVICE

J1 Agricultural restoration and aftercare

Organisations

J1.1 Advice on farming and related nature conservation aspects can be obtained, sometimes at a fee, from or via the following organisations;

- Agricultural Development and Advisory Service (ADAS). Headquarters at Oxford Spires Business park, The Boulevard, Langford Lane, Kidlington Oxford OX5 1NZ (Tel 01865 842742). See also telephone directories under Agriculture for the numerous local offices.
- County Agricultural Colleges. See local business guides under Agricultural Colleges or contact local authority education departments or libraries for addresses.
- Farming and Wildlife Advisory Group (FWAG). Headquarters at NAC, Stoneleigh, Kenilworth, Warwickshire CV8 2LZ but many local offices (see under Farming in telephone directories).

J1.2 National organisations representing the farming and related communities or special interest groups include;

- Council for the Protection of Rural England (CPRE), Warwick House, 25 Buckingham Palace Road, London SW1 0PP (Tel 0171 976 6433). See also telephone directories for local offices.
- Country Landowners Association (CLA), 16 Belgrave Square, London W1X 1AR (Tel 0171 235 0511)
- Countryside Commission, John Dower House, Crescent Place, Cheltenham, Gloucestershire GL50 3RA (Tel 01242 521381)
- English Nature, Northminster House, Peterborough PE1 1UA (Tel 01733 40345). See also telephone directories for local offices.
- Farmers Union of Wales, Llys Amaeth, Queens Square, Aberystwyth, Dyfed SY23 2EA (Tel 01970 612750).
- National Agricultural Centre (NAC), Stoneleigh, Kenilworth, Warwickshire CV8 2LZ (Tel 01203 696969)
- National Farmers Union (NFU), 22 Long Acre, London WC2E 9LY (Tel 0171 235 5077)
- Royal Agricultural Society of England, NAC, Stoneleigh, Kenilworth, Warwickshire CV8 2LZ (Tel 01203 696969)
- Royal Institute of Chartered Surveyors (RICS), 12 Great George Street, Parliament Square, London SW1P 3AD. (Tel 0171 222 7000)

- Royal Welsh Agricultural Society Ltd, Llanelwedd, Builth Wells, Powys LD2 3SY (Tel 01982 553683)

- Welsh Office Agriculture Department (WOAD), Crown Offices, Cathays Park, Cardiff CF1 3NQ. (Tel 01222 825111)

Consultants, contractors and merchants

J1.3 Consultants - see local business guides under Agricultural Consultants, Drainage Consultants. Most agricultural consultants belong to one or other of the following:

- Association of Independent Crop Consultants, c/o Cereals Unit, National Agricultural Centre, Stoneleigh, Kenilworth, Warwickshire CV8 2LZ (Tel 01203 696969)

- British Institute of Agricultural Consultants, Durleigh House, 3 Elm Close, Campton, Shefford, Bedfordshire SG17 5PE (Tel 01462 813380)

- British Institute of Environmental Consultants, 2 Manchuria Road, London SW11 6AE (Tel 0171 978 4347)

- Institute of Professional Soil Scientists

J1.4 Agricultural contractors - see local business guides under Agricultural Contractors or Groundwork Contractors. Trade organisations include:

- Land Drainage Contractors Association, NAC, Stoneleigh, Kenilworth, Warwickshire CV8 2LZ. (Tel 01203 696683)

- National Association of Agricultural Contractors, Huts Corner, Tilford Road, Hindhead, Surrey GU26 6SF. (Tel 01428 605360)

J1.5 Agricultural Merchants - see local business guides under Agricultural Merchants, Agricultural Supplies, Corn and Agricultural Merchants or Seed Merchant.

J2 Woodland restoration and aftercare

J2.1 The key organisation dealing with forests and woodland is the Forestry Authority (part of the Forestry Commission). The Forestry Authority is responsible for setting and promoting standards of excellence for the forestry industry, partly through developing guidelines and giving advice, and by awarding grants to encourage woodland expansion and management. The Authority has national offices in Cambridge, Aberystwyth and Glasgow, and numerous regional offices. It has a statutory duty to advise Mineral Planning Authorities when a forestry after-use is proposed in a planning application. Operators and developers are strongly advised to consult the Forestry Authority at the earliest opportunity if tree planting is planned on a landfill site, preferably before submission of the planning application in the case of new landfills.

J2.2 For more technical advice, expertise can be found in the Forestry Commission Research Division at the following addresses:

- Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH (Tel 01420 22255).
- Northern Research Station, Roslin, Midlothian EH25 9SY (Tel 0131 445 2176).

The local offices of the Forestry Authority may be found in Bulletin 110 or local telephone directories.

Published information

J2.3 Operators considering the establishment of woodland on restored landfall are strongly advised to consult the two definitive works on the subject:

- Dobson M C and Moffat A J (1993) *The Potential for Woodland Establishment on Landfill Sites.* HMSO London. Available from HMSO Publications Centre, PO Box 276, London SW8 5DT (Tel 0171 873 9090). This report describes the work carried out by the Forestry Authority on behalf of the Department of the Environment and includes sections on recommended practices and the economics of woodland planting.
- Moffat A J and McNeill J (1994) *Reclaiming Disturbed Land for Forestry.* Forestry Commission Bulletin 110. HMSO London. Available from HMSO Publications Centre, PO Box 276, London SW8 5DT (Tel 0171 873 9090) or the Research Publications Officer, The Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH. This publication deals with tree planting disturbed land in general including the specific case of landfill site. It contains much practical advice.

Consultants and contractors

J2.4 Operators are strongly advised to use suitably qualified contractors and consultants for the planning, establishment and management of trees on landfill sites. The Institute of Chartered Foresters publishes a list of members in consultancy practice, which can be obtained from The Institute of Chartered Foresters, 7a St Colme Street, Edinburgh EH3 6AA (Tel 0131 225 2705).

J2.5 The Association of Professional Foresters publishes a directory of APF members in business who offer services. It can be obtained from Association of Professional Foresters, 7/9 West Street, Belford, Northumberland NE70 7QA (Tel 01668 213936).

J3 Amenity and nature conservation restoration and aftercare

J3.1 Operators considering restoring all or part of their site to amenity or nature conservation after-uses are advised to consult the following publications;

- Land Capability Consultants (1989) *Cost Effective Management of Reclaimed Derelict Sites* HMSO London. Available from HMSO, Publications Centre, PO Box 276, London SW8 5DT (Tel 0171 873 9090). This report describes the work carried out on behalf of the Department of the Environment on the management of reclaimed land and includes sections on restoration for amenity and wildlife.

- Land Use Consultants (1992) *Amenity Reclamation of Mineral Workings* HMSO London. This report describes research carried out on behalf of the Department of the Environment to provide guidance on planning controls, restoration techniques and short and long term aftercare and management requirements to achieve satisfactory standards of amenity reclamation.

- Land Use Consultants *Reclamation and Management of Damaged Land for Nature Conservation* (in draft). This report describes research carried out on behalf of the Department of Environment.

Organisations

J3.2 The key organisations dealing with amenity and nature conservation are

- local authority Planning, Leisure and Recreation Departments
- Sports Council
- regional offices of English Nature
- Countryside Council for Wales
- Scottish Natural Heritage
- Countryside Commission
- Royal Society for Nature Conservation (RSNC) Wildlife Trust Partnership
- Royal Society for the Protection of Birds (RSPB)
- local authority Conservation Units.

J3.3 For advice and assistance on local ecology and wildlife, the County Wildlife Trusts and local naturalist societies often hold very extensive information.

MANAGEMENT AND CONTACTS:

The Environment Agency delivers a service to its customers, with the emphasis on authority and accountability at the most local level possible. It aims to be cost-effective and efficient and to offer the best service and value for money.

Head Office is responsible for overall policy and relationships with national bodies including Government.

Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol BS12 4UD
Tel: 01454 624 400 Fax: 01454 624 409

ENVIRONMENT AGENCY REGIONAL OFFICES

ANGLIAN
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Fax: 0113 246 1889

NORTH WEST
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Warrington WA4 1HG
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Fax: 01925 415 961

MIDLANDS
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Solihull B91 1QT
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Fax: 0121 711 5824

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Worthing
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Fax: 01903 821 832

SOUTH WEST
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Tel: 01392 444 000
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Reading RG1 8DQ
Tel: 0118 953 5000
Fax: 0118 950 0388

WELSH
Rivers House/Plas-yr-Afon
St Mellons Business Park
St Mellons
Cardiff CF3 0LT
Tel: 01222 770 088
Fax: 01222 798 555

For general enquiries please call your local Environment Agency office. If you are unsure who to contact, or which is your local office, please call our general enquiry line.

ENVIRONMENT AGENCY GENERAL ENQUIRY LINE
0645 333 111

The 24-hour emergency hotline number for reporting all environmental incidents relating to air, land and water.

ENVIRONMENT AGENCY EMERGENCY HOTLINE
0800 80 70 60

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