13 LANDFORM AND EARTHWORKS

Chapter contents

continued...

13 LANDFORM AND EARTHWORKS

13.1 Introduction

For the purpose of this book, the term 'landform' refers to any topographical feature created by Man. Such features will be either superimposed on or cut out of the general topography of the site.

'Earthworks' refers to all operations carried out on site which relate to excavation, removal and deposition of ground materials.

The landforms that are to be found in association with the coal and steel industries are many and various, and existing landforms may be a hindrance to reclamation and after-use or may present opportunities for re-use.

The types of landforms found on coal and steel sites can be divided into two groups:

- landforms associated with the functioning of a site as a colliery or as a steelworks *e.g.* embankments or cuttings for roads and railways, canals, hardstandings, stockpile areas and levelled ground occupied by the works;
- landforms associated with the disposal of wastes *e.g.* spoil tips and lagoons.

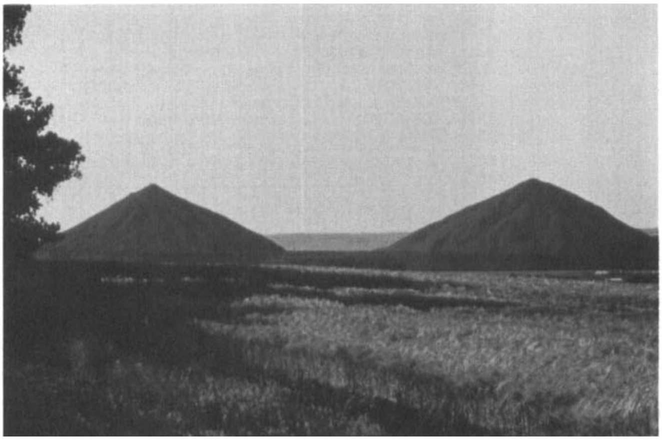
The first group tends to create fewer problems for reclamation and is more likely to have the potential for re-use although this depends on the requirements of the final landform design.

The landforms to be found on coal and steel sites, and their effect on reclamation design, are influenced by the general topography as follows:

- in narrow valleys, spoil heaps will be found occupying the valley bottom, with a profound effect on the character of the area (see Photograph 13.1);
- on flat land, spoil heaps are likely to be very prominent (see Photograph 13.2);
- in hilly areas, spoil may be tipped on a hill top or valley-side and stability may be the most important issue, but in many cases the tips are likely to be a dominant feature in the landscape (see Photograph 13.3);
- areas such as those of buildings, hardstanding and car parks, when located on sloping land, will have required terracing of the original ground;
- steelworks are normally found on flat land, near the coast or along a valley bottom, as they require a supply of water and because of the large size of the associated buildings and structures (see Photograph 13.4);
- for both collieries and steelworks, valley bottoms may be raised to give a flat working area, and for this purpose and also to provide space for tipping of waste, the original river or stream is often culverted (see Photograph 13.1);
- in low lying locations, typically estuaries and coastal plains, large areas of land have been raised using imported fill material to provide sites for steelworks.

A range of other factors which affect the types of landform found on abandoned coal and steel sites are given in Box 13.1.

Photograph 13.1: Former steelworks and colliery, Ebbw Vale, South Wales. The large tips to the left of centre comprise slags, whilst to the right of centre is colliery spoil. The river running along this valley was culverted to provide extra tipping space. This site was reclaimed and used for the 1992 Garden Festival, Wales, UK (source: Welsh Development Agency)



Photograph 13.2: Spoil heaps can be prominent features in the landscape, especially in flat areas. Their height can be lowered by half by removal of just one eighth of the volume of a conical tip (source: Uwe Ferber)

Photograph 13.3: Tipping of spoil in an elevated position. A tip breaking the skyline is especially conspicuous (source: Welsh Development Agency)

Photograph 13.4: Steelworks typically require a large area of level or terraced land, because of their size, and a good supply of water. This steelworks is already partially demolished (source: Richards, Moorehead and Laing Ltd)

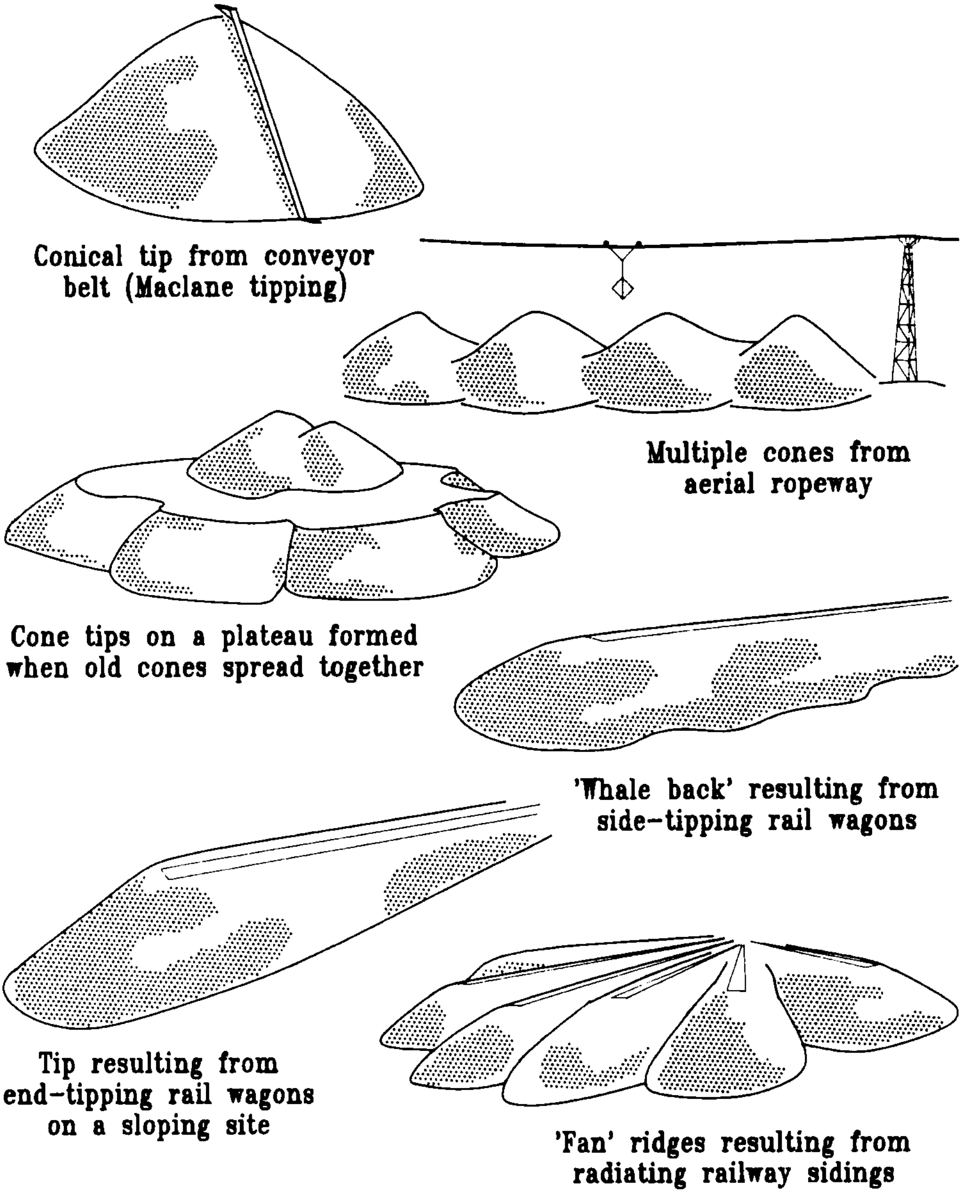
Box 13.1: Additional factors affecting landform

Factors affecting the types of landform found on former coal and steel sites include the following:

- subsidence (see Chapter 3). Subsidence is not limited to the area at the surface where colliery buildings and spoil heaps are located. In flat areas, subsidence can lead to the formation of new water bodies (see Photograph 13.5) which it may be appropriate to incorporate into the after-use scheme (see Section 17.4.5). If not, ground levels will need to be raised and this may provide an opportunity for disposal of spoil materials;
- steel slag, which is often tipped in a molten state, tends to form large, solid masses, with very steep, even cliff-like landforms (see Photograph 13.6);
- underground mining for iron ore tends to produce spoil heaps and subsidence problems similar to those to be seen at coal mining sites;
- the basic shape of spoil heaps is determined by the method of tipping (see Figure 13.1);
- the form of spoil heaps is often dictated by the area of land available at the time of tipping and the volume to be placed on that land (see Photograph 13.7);
- tipping of colliery waste was often more wasteful of space in the past than in modern operations;
- modern tipping often results in a general raising of the ground level, rather than the creation of a distinct spoil heap;
- older tips are loose-tipped and therefore less consolidated than modern 'constructed' tips (see Chapter 6).

Photograph 13.5: Subsidence of the ground surface following deep mining can lead to the formation of new water bodies. The lake in the right foreground is used for fishing and other recreational activities (source: EPF)

Photograph 13.6: These 'bluffs' formed of steel slag tipped in a molten state, were retained and utilised as a dramatic feature in the 1992 Garden Festival, Wales, UK (source: Richards, Moorehead and Laing Ltd)



In recent years, tip construction by lorries, box–scrapers, bulldozers, *etc.* has frequently occured, creating further variety in tip shapes.

Figure 13.1: Shapes of tips resulting from the method of tipping (after Tandy, 1975[234])

Photograph 13.7: Shortage of tipping space can determine the form of spoil heaps and can be a severe constraint on reclamation options (source: Welsh Development Agency)

The issues arising from the various landforms found on derelict coal and steel sites can be summarised as follows:

- scale with respect to surrounding areas of land;
- actual size;
- location within the site;
- constraints on after-use caused by landform ('hard' after-uses are more specific in their landform requirements than 'soft' uses and therefore tips of waste material often provide fewer constraints to 'soft' after-uses);
- opportunities for re-use provided by the landform as it exists;
- re-use potential of waste materials;
- stability of waste heaps (see Chapter 6);
- materials with difficult handling and chemical characteristics (see Chapter 5 and 9);
- subsidence of land and possible flooding (see Chapter 3);

- visual aspects such as shape, prominence, colour and texture;
- vegetation cover;
- relationship with the surrounding landscape;
- waste heaps may have become an accepted part of the local scene and may even be regarded as an amenity by local people;
- undisturbed tips may be an important element in the history of the site, illustrating techniques used at various times;
- undisturbed tips can be of mineralogical and ecological value;
- expense - changing unsafe or inappropriate landforms usually involves considerable engineering works.

For any of the above reasons, there can be a need either to amend and remodel or to retain the landforms on a site. This chapter discusses various aspects of landform remodelling, covering the need for remodelling of landforms, the various approaches to and constraints on remodelling, the design process and technical aspects of remodelling.

13.2 The need for remodelling of landforms

Reshaping landforms is often necessary and the reasons for remodelling of landforms fall within the following categories:

- instability;
- presence of hazardous materials;
- visual considerations;
- land-use needs or opportunities;
- re-use potential of materials.

The reasons for landform remodelling are further discussed in Box 13.2.

Whilst there can be many good reasons why landforms should be changed, it is important that the design team critically examine any ideas for such changes. On abandoned sites, landforms often mellow with age, and if they are safe, can sometimes be retained as benign reminders of

Box 13.2: Reasons for remodelling of landforms

The following questions should be asked by the design team to determine whether remodelling of landforms is necessary:

- is there a hazard, or potential hazard, present on the site, such as unstable tips or abandoned lagoons?
- is the site visually intrusive? Can detrimental impact be reduced or eliminated by remodelling?
- is there a need to clear away or modify inappropriate landforms, or create new ones, to cater for the proposed after-use and the long-term management of the site?
- would remodelling add to the prospects for economic regeneration in the area, through improvement of the environment or provision of developable land?
- would there be benefit from creation of variety of landform on a site which is currently very bland?
- even if the shape of the landform is usable, does the ground offer adequate bearing capacity for the proposed after-use?
- could remodelling serve to reduce or eliminate erosion, by reducing gradients and assisting vegetation establishment?
- would remodelling offer the opportunity to create useful barriers between different land uses e.g. for screening, noise baffling or dust control?
- is the existing landform causing problems with drainage, perhaps leading to flooding, which could be resolved by remodelling?
- would remodelling offer the opportunity to remove, treat or encapsulate noxious materials, or even produce a disposal site for imported waste?
- is there saleable material on the site which requires tips to be reworked, and can this be used to generate income e.g. coal content of old colliery spoil tips, use of spoil as inert fill for road construction, as cover material on domestic waste sites or to create new land elsewhere; or seams of coal which are now economically workable by opencast mining but are buried under tips?

the industrial past. Indeed, there is an increasing recognition of the merit of retaining historical features on old industrial sites and, more significantly, that the site as a whole forms an historical landscape which may be of some considerable value.

Methods of assessing the historical value of a site are explained in Section 2.7. Box 13.3 expands on some of the arguments for retaining spoil heaps.

Abandoned tips may be perceived as aesthetically unacceptable features for three reasons:

- their historical connotations, being symbolic perhaps of a low standard of living and environmental degradation;
- their location amongst the surrounding scenery *e.g.* pleasant countryside or areas of housing;
- their visual characteristics *i.e.* bulk, height, colour and shape.

The first reason for objecting to the continuing presence of waste tips *i.e.* their historical connotations, is dependent on local and individual attitudes. Acceptance of the historical significance of industrial relics can reduce or even eliminate any objections based on the second and third reasons.

When considering the visual impact of abandoned industrial sites, it should be recognised that whilst waste tips may be the most noticeable features of the landscape, due to their sheer size and bulk, the associated derelict buildings, redundant equipment and other artifacts may be at least as significant in an assessment of the visual quality of a given area. These features can collectively form an untidy mixture of unwanted and irrelevant materials, with harsh, unnatural shapes and colours.

Box 13.3: Some arguments for the conservation of spoil heaps

There are a growing number of examples where removal or reclamation of spoil heaps has been resisted, either by specialist interest groups or the general public. The following examples illustrate this trend, relating to the conservation of heritage, wildlife and fossils.

1. In North-East England, a public inquiry was held in 1990 to examine proposals to reclaim the site of the former Kilton iron ore mine. After hearing evidence from two in favour and twenty four against reclamation, the Inspector wrote in his report that he considered that the tip was not an eyesore nor a disincentive to local economic development. It had a role to play in the development of tourism in the area as an historical feature in the landscape and he considered that the proposed scheme would be detrimental to the very wildlife it was claimed would benefit from it. In fact the Inspector found evidence that the shale tip at Kilton was now a uniquely recognisable industrial archaeological relic in East Cleveland, and concluded that the advantages of its retention far outweighed the benefits of its removal.

   The Inspector's recommendation that the scheme should not go ahead was accepted by the Government.

2. In the coal basin of Nord-Pas de Calais, in the North-East of France, over 250 colliery spoil heaps have been formed. Some have developed a vegetation cover of significant ecological value. Alpine species, which are adapted to poor, stoney soils, and species from the south of France which tolerate hot conditions, have colonised some of the tips.

   This ecological value has been recognised in some instances, for example on tip no. 36 at Noeux-les-Mines. There, a stairway was constructed to the summit, in association with the local naturalists society, to safeguard the rare species on the site. On the Pinchouvalle tip, one of the most imposing in the region, reclamation proposals were orientated towards exclusive use of the site for nature conservation and related activities, including habitat conservation, paths and observation points.

3. In an article entitled "Britain's tip heaps - an unlikely subject for conservation?"[6] the author highlights the fact that colliery spoil heaps can be "store-houses of irreplaceable scientific specimens of fossil plants, fish, amphibia and insects". The soft rocks of the coal measures are rarely seen in natural exposures and the mines are normally inaccessible, so the tips themselves can provide a unique resource for study. Examples are quoted where the fossil content of tips are of international importance and cases are cited where material was salvaged from tips, for subsequent study, before reclamation.

In summary, the overall objectives of landform remodelling are to ensure that:

- the land is safe;
- the land is usable;
- the land can be managed economically;
- the quality of the local environment is enhanced;
- economic regeneration is accelerated by creating new landforms which can accommodate a particular new development (see Photograph 13.8).

13.3 Approaches to remodelling landform

13.3.1 Introduction

Where the landform is to be remodelled well prepared reclamation proposals will address the constraints resulting from the past use of the site and will look to the future, by preparing the way for the preferred after-use.

The relationship between landform and after-use is fundamental. The landforms that exist on a site may be suitable only for some uses and may therefore influence decisions on after-use. Alternatively, landforms may have to be amended to suit the required after-use (see Section 13.6.5 and Box 13.12). If final after-use is uncertain at the time that reclamation works are being designed, a landform which provides flexibility of use is then advantageous. Generally, however, a better solution will be produced if the landform can be designed for a specific use, which is then implemented.

A considerable amount of time may elapse between the completion of reclamation and final development of the after-use. The full benefits of remodelling will not be felt until development is complete and it is important in the achievement of local acceptance and continued support that local people realise why reclamation was carried out in a particular way.

Photograph 13.8: The location of this site close to housing and in a flat, open landscape suggests a need for reclamation, including remodelling of the tip. In locations like this, there is no obvious need for creation of new development land, but the environmental improvements that can be brought about by reclamation are important in the promotion of economic regeneration (source: EPF)

Both administrators and designers need to be aware that, because of changing economic, social and technical factors, justification can arise for the remodelling of land which has already been reclaimed.

In the remodelling of landforms, there are three broad options to be considered. These are:

- the retention of the landform;
- minimal interference;
- major earthworks.

The rationale behind the first option, where existing landforms are retained for historical or other reasons, was discussed in Section 13.2.

The possibility of minimal interference is an important option, since if satisfactory results can be achieved at lower cost than by major earthmoving operations, a greater area of reclamation is facilitated for the same expenditure. Relatively minor changes to a landform can substantially reduce its visual impact. Similarly an unsatisfactory landform can be disguised by planting with trees and shrubs rather than being reshaped. Where a suitable after-use can be identified which requires no reshaping of the landform, consideration needs to be given to whether remodelling to suit another more demanding after-use is really justified. This approach to reclamation is particularly applicable to amenity after-uses and is discussed in Box 13.4.

It is important always to consider a combination of options within one site. Coal and steel sites can be very large and very variable in both their problems and their potentials. An over-simplistic approach may be wasteful of resources or produce an inferior result. For example, major earthworks may be required in one part of a site but another part could be retained as it is, conserving mature vegetation, thus reducing overall costs and producing a more sensitive and interesting scheme. On the other hand, one must guard against over-complication which can make the implementation of reclamation proposals difficult and expensive.

13.3.2 Major earthworks

Major alterations to a landform may be undertaken:

- reworking of tips for saleable material which, in conjunction with good planning, can produce an improved landform as part of a reprocessing operation;
- removal of waste materials for use off site, the feasibility of which will depend on transport costs compared with the value of alternative materials;

- reshaping on site, with no export of material, by spreading out materials, creating new landforms or filling holes and depressions;
- reshaping on site in conjunction with opencast coal mining;
- reshaping in conjunction with the treatment of contaminated land;
- importation of waste materials from elsewhere, to be incorporated into a new landform on site.

Box 13.4: Reclamation without remodelling

Reclamation schemes involving large scale regrading of waste heaps or extensive civil engineering works inevitably involve considerable expenditure. This expenditure may be justified in order to remove hazards or to prepare land for development, but such expenditure is harder to justify for the provision of less intensive uses such as informal recreation, nature conservation and landscape improvement.

Revegetation techniques (see Chapter 14) have been developed which allow many derelict sites to be returned to the use of the community with a minimum of expenditure on earthworks. These techniques widen the choice of practical land reclamation approaches, and widen the range of objectives which are economically feasible.

These revegetation techniques form part of a 'low-cost philosophy' which may be summarised as five simple points:

- involve the public in the choice of after-use;
- match the after-use with the existing site features;
- match the intended vegetation types with the characteristics of the site;
- work towards the long-term development of the vegetation;
- work with nature rather than against it.

This low-cost approach is not a substitute for conventional civil engineering in schemes involving construction or land remodelling for urban or industrial uses, but it can play a valuable part in the treatment of non-development areas within such schemes.

Within these possibilities, there are two fundamentally different approaches, namely to produce either a 'naturalistic' or an 'artificial' landform. Circumstances will dictate which is the more applicable of the two end results.

The naturalistic approach seeks to emulate natural landforms and is particularly applicable to rural sites, and with after-uses such as agriculture, forestry, nature conservation and informal recreation. Figure 13.2 shows a selection of naturally occurring landforms which can provide inspiration for the remodelling of tips. Removal of harsh lines and angles, as well as reducing the height and softening the bulk by planting, can produce results which blend very satisfactorily with the surroundings (contrast Photographs 13.9 and 13.10). Such work must be designed and implemented with sensitivity and be in keeping with the locality.

The artificial approach, in contrast, is likely to be more applicable on urban sites and for after-uses such as built development and formal recreation (see Photograph 13.11). In these circumstances, emulating natural topographical features would not produce the required landforms. The artificial approach also includes the possibility of innovative landform design by artists or sculptors, sometimes known as 'earth art'. Examples are shown in Figure 13.3.

Both the natural and artificial approaches encompass the following:

- the opportunity to use the sculptural effect of landform in an aesthetic way, to provide a sense of enclosure, separation, contrast, or drama and in the creation of watercourses and water bodies;
- the opportunity to shape the land to suit the specific requirements of certain after-uses which would not otherwise be possible;
- the opportunity to recreate previous landforms, be they relics of the industrial past which have been disrupted by subsequent activity, or the pre-industrial topography itself.

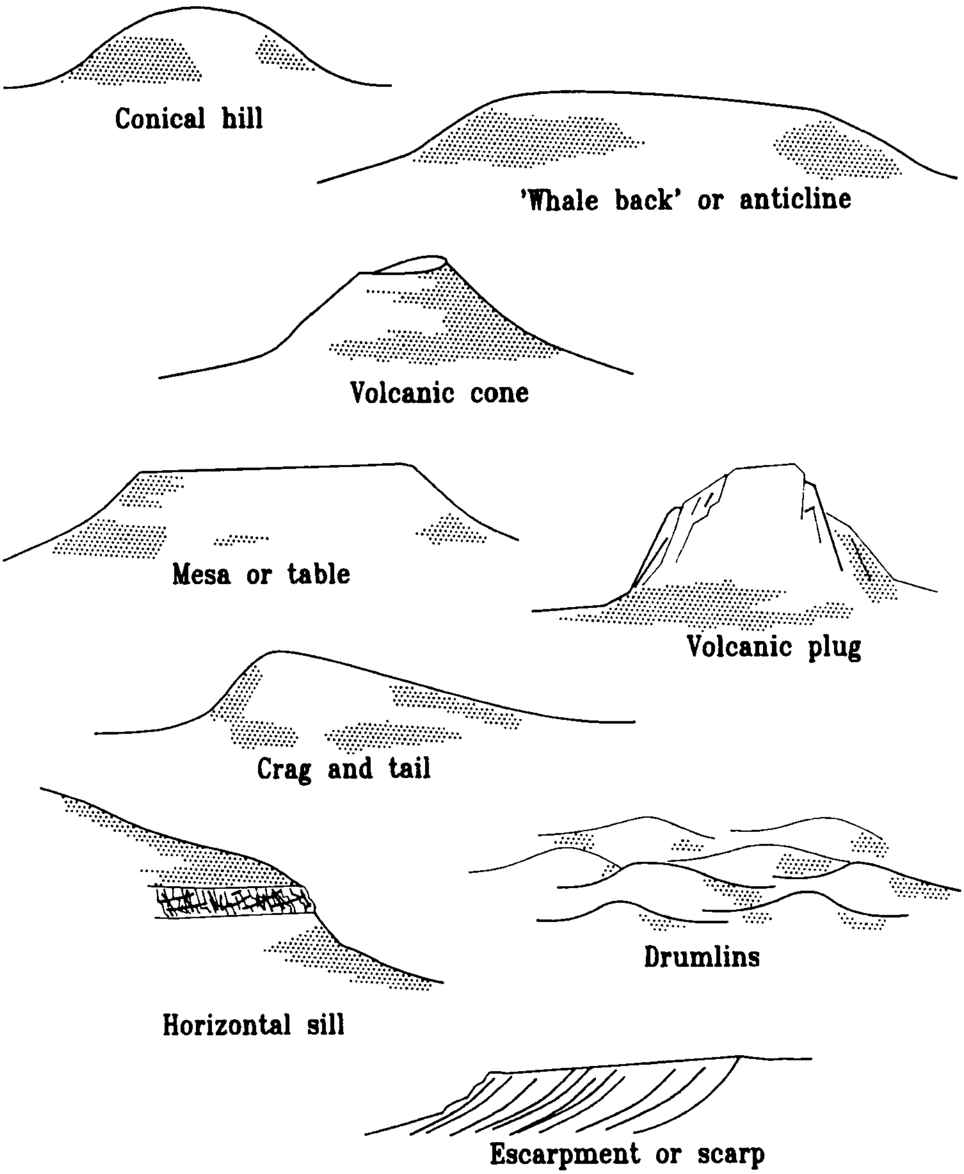
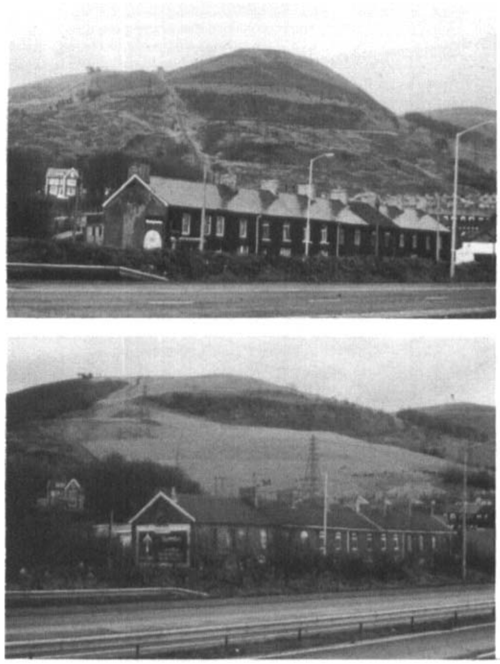
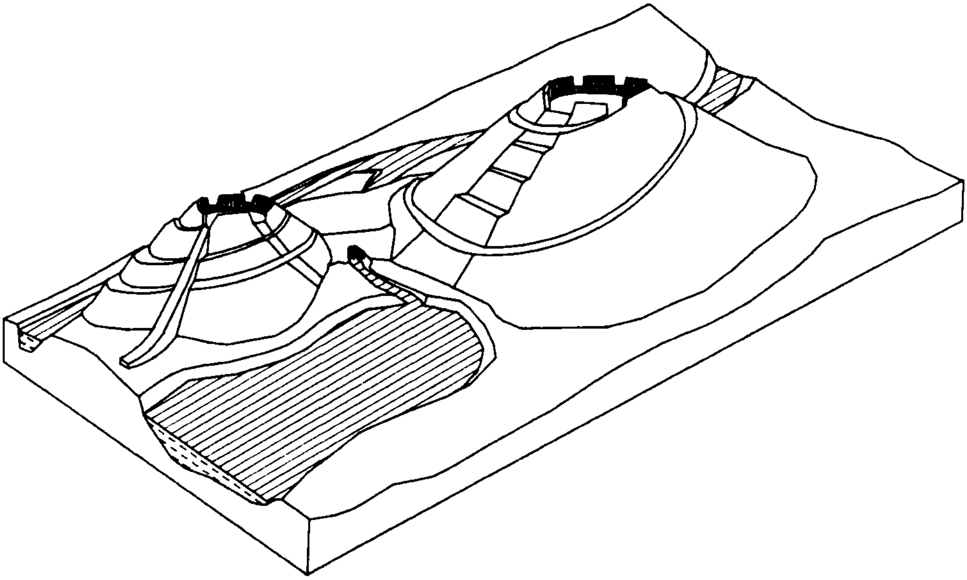


Figure 13.2: Some naturally occurring landforms (after Tandy, 1975[234])



Photograph 13.9:
Reducing the height and bulk of this tip, removing the prominent straight line of the incline and greening the spoil all contributed to the blending of this site with its surroundings. With time, tree planting would further enhance the effect (source: Welsh Development Agency)

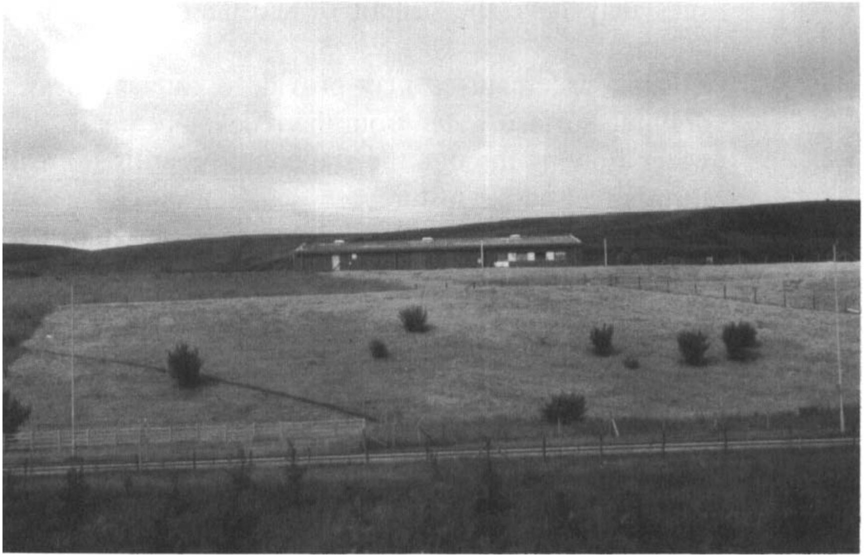
Photograph 13.10: In contrast with the scheme shown in Photograph 13.9, treatment of this site concentrated on producing a stable grassed landform but failed to integrate the site with its surroundings (source: Richards, Moorehead and Laing Ltd)



The smaller cone was proposed as an alternative to covering the foreground and adjoining farmland with the last output of waste from the colliery. The lake is converted from old sludge lagoons (after Tandy, 1975).

(source: Mike Petts)

Figure 13.3: Examples of innovative landform design



Photograph 13.11: Reclamation schemes which prepare land for industry, housing, sports pitches, etc. require the formation of level, terraced or gently sloping ground. Such schemes are often designed to maximise developable space, by using steep and regular batters, with the consequence that the new landform has an artificial appearance. A landform of this type can be softened or disguised by plentiful tree planting (source: Richards, Moorehead and Laing Ltd)

13.3.3 Utilising existing site features and characteristics

Having carried out their site assessment, the design team should be fully aware of the opportunities presented by the site. For example:

- the location, size and shape of a site may lend itself to a particular purpose;
- materials found on site can have useful engineering qualities such as strength and durability;
- there may be a good view from an elevated landform;

- sites may have the benefit of substantial infrastructure and utilities;
- existing watercourses may provide a convenient system for draining surface water from the redeveloped site;
- water flowing through the site could be utilised creatively to form an attractive feature;
- existing vegetation can be retained to provide a sense of maturity to the scheme, or to maintain the stability of a steep slope;
- older tips may be well colonised by vegetation of ecological value;
- there may be materials on site which are more suitable as a growing medium than others, and/or would encourage ecological diversity if used appropriately (see Box 13.5, Section 13.3.4). These materials should be identified and saved for future use;
- terraces formed for buildings and the buildings themselves can be re-used;
- existing features of historical value can be retained and incorporated into the scheme;
- existing landforms may be useful for specific after-uses *e.g.* long, steep gradients for dry-ski slopes, undulating areas for off-road motorcycling, or large, evenly graded areas for industrial development, housing or playing fields;
- it may be desirable to retain tips, or parts of tips, for their mineralogical or fossil value (see Box 13.3) and for study of the processes which produced the waste;
- intricacy of landform can be retained to ensure variety, both visually and ecologically.

13.3.4 Other general principles

There are other general principles which influence the approach to earthworks design:

- after-uses such as heavy engineering, light industry, housing and sportsfields have specific requirements as regards minimum area, shape and surface gradients which will determine the scale of the earthworks required when these uses have to be accommodated;
- in order to reduce long-term maintenance liabilities it is useful to minimise the reliance on constructed features, by integrating the design of landform, drainage and vegetation (see Photograph 13.12);
- there is a need, in most cases, to minimise maintenance liabilities, therefore a stable landform, healthy vegetation and robust drainage are desirable qualities;
- incorporating variety of slope, drainage, and surface materials in the scheme will enrich a site in visual and ecological terms (see Box 13.5). This should be considered both at the macro (whole site) scale, where the site is seen in the context of its surroundings, and also at the micro scale, where either restoration of the local 'grain' of the landscape is sought, or new local interest is created around buildings;
- modification of microclimate can be very beneficial, to create shelter, make best use of aspect and sunshine, avoid frost hollows, or create noise baffles and security bunds;
- vegetation and buildings on adjacent land can change and these changes can lead to masking or exposure of the reclamation site.

When considering the possible reshaping of the land the design team should assume that the landform will be permanent, and so should design for the best possible result.

Photograph 13.12: Integration of landform, drainage and vegetation. Vegetation softens the appearance of a ditch provided for occasional storm-water. Gentle side slopes also reduce visual impact (source: Welsh Development Agency)

13.4 Constraints on remodelling

13.4.1 Introduction

There is increasing potential for interesting and diverse reclamation schemes, because of:

- increasing knowledge and experience;
- improving technical skills;
- improved machinery;
- computer assistance;
- an increasing awareness of the benefits of multi-disciplinary design teams;
- availability of funding for post-reclamation development.

Box 13.5: Landform modelling for ecological diversity

Diversity of habitat and diversity of species are valuable characteristics of sites where wildlife conservation is an objective. These characteristics can be encouraged by the construction of a diverse landform, containing a range of:

- slope angles;
- aspects;
- exposure and shelter;
- drainage conditions;
- substrate textures;
- substrate pH;
- substrate nutrient concentrations.

Diversity of plant species is encouraged by neutral or alkaline pH and low nutrient concentrations which prevent a few vigorous, competitive species outgrowing all others. The wastes found on abandoned coal mine sites and iron and steel works are inherently infertile, and have a range of textures and pH values. Landforms and drainage conditions can be manipulated by civil engineering works. The different substrates can be mixed to produce gradations of physical and chemical characteristics.

Landform diversity can be designed to produce or favour specific habitats and vegetation types, either in a scheme which is to be fully vegetated at completion, or where the new landform is left to revegetate by natural colonisation (see Box 14.4). The vegetation and substrates recorded during pre-reclamation surveys can provide a guide to the range of habitats which could be designed into the scheme. Working together, the ecologist, civil engineer and landscape architect can produce a landform which will support a range of habitats and species.

There remain, however, factors which will limit the options in relation to landform design and creation. These are described in the rest of this section, under the following headings:

- land;
- materials;
- reclamation techniques;
- timing and season;
- after-use and management;
- costs.

13.4.2 Land

The extent of the site may be defined by ownership and/or by surrounding land-uses (see Photograph 13.7). Such boundaries may limit the scope for spreading out waste materials in order to reduce the height of tips.

If major reshaping of tips is anticipated, the design team should be given the opportunity to consider the amount of land needed in advance of land acquisition, so the best reclamation options may be produced.

One objective of reclamation may be to reduce the visual impact of a tip by the blending of landform and land-uses with the surroundings. The higher the tip, the flatter the landscape and the more confined the site, the more difficult this will be to achieve. Photograph 13.2, showing tips in northern France, illustrates this point. The same problem occurs in mine tips in the Ruhr area of Germany:[33]

> "Adapting the slag-heaps to fit with the mainly flat landscape of the coal mining area is problematical. Large masses of material to be dumped over a small space and the often immediate proximity of settlements make the problem even more difficult or quite impossible. Dumps 40 to 90m above ground level are bound to break up the landscape. Whether they are regarded as disturbing elements mainly depends on their shaping, landscaping and possibilities for later use."

Removal of tips will usually benefit neighbouring properties, but there are circumstances where it can be to their detriment. For example, the sheltering effect of an old tip may be lost, or a new but unattractive view may be opened up.

13.4.3 Materials

The materials to be found on site may constrain the reclamation process in a number of ways:

- the chemical and physical characteristics of a material will affect its compatibility with the proposed after-use (see Chapters 5 and 9);
- the cost of moving material about a site depends on the quantity and also the distance that it has to be moved;
- the natural angle of repose of a material cannot be exceeded without special measures to retain or stabilise the slope;
- regraded material may require special treatment before it will support the proposed after-use;
- the handling characteristics of the materials will determine the ease of moving them;
- the nature of the materials on site will affect drainage needed during the works;
- there is likely to be a need for a volume balance of materials within the site;
- the degree of compaction before and after moving affects the volume of material and therefore the final levels. Also, compaction after moving makes vegetation establishment more difficult, and uneven compaction can lead to differential ground settlement;
- the production of excessive dust in dry weather should be prevented;
- the potential for ignition of combustible materials should be anticipated;
- disturbance of an old tip can expose fresh spoil and lead to the loss of weathered material which is more amenable to plant growth.

13.4.4 Reclamation techniques

The current best practice will always set the limits on what can be done and at what cost. Design of a scheme such that available techniques allow reasonably economical implementation is a normal requirement. For example, an understanding of the abilities and limitations of earthmoving equipment is important in this respect. Without this understanding, proposals may be produced which are impractical or expensive to implement. Relevant to this issue would be a wish to design a varied and interesting landform. The right balance has to be found between variety in the result and the practicality of its creation.

13.4.5 Timing and season

The timing of implementation is significant for several reasons:

- weather and ground conditions significantly affect earthworks operations. For example, in the winter heavier rainfall can require temporary drainage during the works and the ground may be so wet as to prevent earthmoving operations continuing. Conversely, dry conditions can lead to problems of the raising of dust by vehicles. Dust production can be a particular nuisance at burning colliery tips (Box 13.6);
- the timing of earthworks should be planned so that they coincide with the seasonal requirements of vegetation. For example, a grass sward may be needed to prevent surface erosion, but grass can only be established in the right season, dictated by local climatic conditions;
- social and economic factors can both affect the progress and timing of reclamation schemes, possibly overriding the plans of the design team. Rapid progress may be required to meet the demands of the local community, and funding may be linked to strictly controlled financial periods of the year. Such factors will usually be outside the control of the design team.

Box 13.6: Weather conditions and their effects on earthworks.

Problems with earthworks can arise as a result of either wet or dry ground conditions.

Wet ground conditions
Only a relatively small proportion of rainwater will penetrate to a significant depth in a well-established and undisturbed colliery spoil tip. However, if the surface is disturbed, water penetrates much more readily resulting in saturated conditions in the layers near the surface. Surface erosion will be encouraged under these conditions and a previously stable tip can, subject to the amount of rainfall, become unstable.

Excavation of an old tip therefore requires consideration of how water penetration or its effects can be reduced, with provision of temporary civil engineering measures, such as cut-off drainage and embankments.

Dry ground conditions
Dry conditions can lead to problems with dust. This is especially so with sites subject to burning. However, reclamation contractors often prefer to work during the winter because, compared with other types of site, the ground conditions can be less saturated, thus allowing fuller use of earthmoving equipment. Winter working will reduce the dust problem.

The earthworks contract should include clauses which restrict working in conditions where dust blow would be a problem. Mobile water sprayers can be used to control dust generation, especially on haul roads.

In addition to these precautions, dust monitoring equipment can be installed on and around a site. Even if dust control precautions are successful, monitoring can be useful for public relations purposes *i.e.* to demonstrate to local residents that the potential dust problem is well controlled.

Restrictions on earthmoving
Large scale earthmoving will typically involve spoil and slags. Spoil derived from coal measures tends to be soft, breaking down rapidly when subject to weathering and also when moved in a very wet or saturated condition. Slags derived from iron and steel making are generally hard, brittle and not degradable. When moved in wet conditions, colliery spoil tends to become impermeable and slags retain their permeability.

Specifications for earthworks should restrict the moving of colliery spoil by reference to moisture content which should then be measured on a regular basis. Alternatively, based on experience, earthmoving can be controlled by the engineer using rainfall records maintained on site and judgement on the day by day condition of the spoil. In prolonged periods of wet weather, earthmoving is commonly brought to a complete stop.

Movement of slags in wet weather does not raise any serious problems and conventional earthmoving techniques and practices will be found to produce acceptable results.

It is advisable to ensure that potential contractors are aware of the expected timing of reclamation works and are provided with comprehensive site investigation data on ground and climatic conditions.

13.4.6 After-use and management

A scheme will be judged by the end-result of reclamation, not the process of reclamation, and not by comparisons of the site before and after treatment. Therefore:

- topography must relate to the gradient limits of the proposed after-uses and also to the management of the site (see Boxes 13.12 and 13.13);
- the right balance between flexibility of after-use and design for a specific purpose has to be achieved;
- the results of reclamation should be both aesthetically good and technically sound. This will place significant limits on the options for landform design and creation.

13.4.7 Costs

The financial implications of proposals to remodel the topography of a site are likely to be very significant. Because of transport costs or waste disposal limitations, earthworks will be frequently limited to a balance of cut and fill within the site. Where the need for developable land is a priority, it may be necessary to consider spreading material on to neighbouring land, but this is likely to introduce an extra cost through the need to acquire land which may not be derelict. Where some income can be generated by the reclamation work, this will be of great help in promoting the scheme, as will creation of land with development potential (see Section 13.2).

13.5 The design process

13.5.1 Introduction

Competence in design is learned through training and experience, and the following aspects are discussed in this section:

- team work;
- the holistic approach;
- design for after-use;
- earthworks design;
- implementation.

13.5.2 Team work

Good reclamation design is the result of team work and this general principle applies equally to the more specific topic of landform design. Successful team work depends on the establishment of clear objectives, the application of discipline and ultimately the performance of team members. The multidisciplinary nature of reclamation work demands project leadership and good project management if the work is to be successful.

The main professional disciplines relevant to landform design are civil engineering and landscape architecture. Others which have a bearing on the subject include:

- geotechnical engineering;
- geology and hydrogeology;
- soil science;
- geomorphology;
- ecology;
- other environmental sciences;

- planning;
- forestry;
- horticulture;
- bioengineering;
- industrial archaeology.

13.5.3 The holistic approach

All relevant issues should be identified and considered and, through an analytical approach, solutions sought which satisfy all reclamation objectives. This holistic approach should develop naturally if the team includes the necessary disciplines and works together effectively. The following paragraphs provide a few examples of this approach.

The surroundings of a site provide the setting for the new landform and land-uses and provide clues to assist in the design of the scheme. Both the surroundings and the site itself should therefore be studied to achieve the best design.

In the early stages of the design process, the team should be searching for both the positive attributes of the site and any problems to be dealt with. There may be features or characteristics which merit incorporation into the scheme. Section 13.3.3 of this chapter lists many of the possibilities. A temptation to clear a site and start again in all respects is usually wasteful and should be avoided.

It is best not to become involved in detail too soon in the design process, and to consider the options and agree the general principles at an early stage.

The practical constraints and opportunities identified at the site assessment stage, together with the objectives for reclamation, will form the basis for new proposals. Imagination and vision are also needed to produce the best solutions.

13.5.4 Design for after-use

Determination of the after-use of a site is fundamental to good reclamation, and this applies as much to landform design as to any other aspect. Considerations of after-use need to operate at two levels; land-use planning and site planning.

Land-use planning provides the overview which determines the general viability of proposed after-uses and ensures that zoning of after-use is compatible with the surroundings.

Site planning is the subsequent process which fits the proposed after-uses to the site, and *vice versa*. Site planning will thus aim to define the following:

- the location, size and disposition of all after-use features;
- appropriate communication links with surrounding land;
- an achievable and cost-effective layout;
- integration of landform, drainage and vegetation with each other and with the after-use(s);
- suitable microclimate and ground conditions for the after-use(s);
- a site which will be physically stable and manageable in the long-term.

The site planning process should, with all but the very simplest site, lead to the production of a masterplan (see Section 2.2).

It is important that a masterplan is realistic in what it shows, but there is no need to design a scheme with great precision at the preliminary stage of the design process.

A masterplan which shows the proposed after-use of a site is very useful to the reclamation team, who can use it to ensure that they design a landform that will be well suited to the after-use.

13.5.5 Earthworks design

The starting point for the design of earthworks is a plan of proposed after-uses as described in Section 13.5.4. This plan will allow the design team to draft landform proposals, using rough sketches and a topographical survey, contour plans and cross-sections. Alternative schemes may well be examined at this stage and rough costings will be needed to enable comparison and to ensure cost-effectiveness.

Various techniques are available to assist comprehension of the proposals and to communicate ideas:

- a general plan to provide an overview of proposals;
- cross-sections showing existing and proposed topography;
- perspective sketches, often referred to as 'artists impressions';
- computer constructed perspectives, which can be invaluable in creating reliable visualisations;
- photomontage, where perspective artwork is combined with a photograph to give an impression of realism;
- physical models, which offer a full exploration of the three dimensional implications of a scheme;
- video films can be created to simulate the experience of passing through a site, either using a model and a special camera or by using computer generated images.

As well as exploring the appearance of the proposals, it is also important to consider where the proposed landform could be seen from and, conversely, what will be visible from the new landform.

Once draft proposals are agreed which satisfy the objectives of reclamation, the proposed after-uses and aesthetic criteria, it is necessary to calculate the volumes of cut and fill material. With experience, the design team will have produced a draft scheme which is already close to providing the necessary balance of cut and fill.

There are a number of ways to calculate earthworks volumes:

- formulae;
- the grid method;
- the contour method;
- the cross-section method;
- physical models;
- computer models.

The principles, advantages and disadvantages of these methods are described in Box 13.7.

All methods of volume calculation need to take into account the degree of compaction of materials as existing and as required, using information on the likely factors of increase or reduction in volume.

Volume calculations will enable rough costings to be refined. Subsequently, if the scheme is being designed to be within a fixed budget, modifications to landform volumes can be undertaken.

There should be full integration of the proposals for landform, drainage and vegetation, to ensure an efficient and effective scheme.

13.5.6 Implementation

Once a feasible scheme has been formulated, communication of the design intentions to those responsible for implementation is necessary to obtain approvals from authorising bodies and to inform firms at tender stage and contractors during site work. Effective communication is achieved through a combination of drawings, written information and person to person contact.

Box 13.7: Methods for calculating earthworks volumes

Earthworks design cannot proceed very far before volume calculations are needed. At first, rough approximations are adequate, so methods of calculation can be relatively simple. As the design progresses, increasingly precise calculations are needed, especially if a balance of cut and fill is required.

1. Formulae - for slopes that approximate to simple geometric forms, volumes can be estimated by mathematical formulae.

2. Grid method - uses the change of level between existing and proposed surfaces, at a network of points over the site. More suitable for simple landforms. Useful for rough comparison of alternatives.

3. Contour method - convenient for simple landforms, this uses the volume of each 'slice' of ground represented by a contour.

4. Cross-section method - using measurement of the area of cross-sections through the landform, drawn at regular or selected intervals, this method can produce reliable figures. Frequently the favoured method, but is time consuming if done thoroughly enough to give accurate figures.

5. Physical models - have been used for volume calculation, using photogrammetry. Useful for large and complex schemes. A volume balance is achieved early on in the design process. Provides an indication of how material will have to be moved around the site. Has other benefits - visualisation of proposals and wind-tunnel tests.

6. Computer models - using digitised data, the method allows convenient comparisons of options, rapid and accurate calculation of volumes and production of cross-sections and also accurate visualisation. Often too costly for small schemes but very cost-effective for large or complex ones.

Communication should be as clear and precise as possible and should include:

- information on the nature of materials;
- results of special surveys/investigations;
- plans and cross-sections showing the existing situation and proposals;
- volumes to be moved;
- haul routes to be used;
- requirements as to placement of materials;
- health and safety requirements, including dust control;
- any other restrictions on working methods;
- specifications of either methods of working or performance required.

13.6 Technical aspects of landform remodelling

13.6.1 Introduction

The techniques for remodelling derelict land are described here with emphasis on those elements of particular relevance to the reclamation of coal and steel sites.

13.6.2 Topographical survey

A fundamental tool in the remodelling of landform is a good quality survey of the existing topography and site features (see Section 2.4.2). It should preferably be extended into the surrounding areas of land.

The survey can be produced either from aerial photographs by the process of photogrammetry, or by ground survey. Modern electronic survey equipment has revolutionised ground survey techniques and productivity. Box 13.8 provides a comparison of the two techniques.

Box 13.8: Comparison of aerial and ground survey methods

Despite the major improvements in ground survey equipment, aerial survey still gives a more realistic (though less precise) representation of the land surface, and is more economical than a ground survey for a complex site. Aerial survey also avoids possible difficulties with access to private land.

The main disadvantage with aerial survey is that, on vegetated areas, the actual surface of the ground is obscured, so height information is inaccurate or absent altogether. This problem is worst when the existing vegetation is tall and dense, comprising thick scrub or woodland.

Aerial photography for mapping purposes is best carried out when deciduous trees are not in leaf. Evergreen species are particularly troublesome because they obscure the ground throughout the year.

The acquisition of aerial photographs will assist the design team, even if they are not used to produce the survey, since they provide a detailed record of surface features.

The use of computer programmes for the modelling of land surfaces has provided a new method of earthworks design to the design team. The topographical survey in digital form is compared to a proposed landform and the volumes of cut and fill are calculated with greater speed and accuracy than manual methods (see Box 13.7). A more interactive approach to landform design is facilitated whereby more options can be examined and compared, because the volume calculation process is so rapid. Furthermore, as the model is in three-dimensional form, it can be viewed from any angle, with true perspective, providing views to assist with the visualisation of proposals.

Computerised surface modelling systems can also be very beneficial when setting-out proposals on site. See Box 13.9 for details.

Box 13.9: Computer surface modelling as an aid to setting-out on site

A surface modelling system can be used to produce quickly the cross-sections through the existing and proposed landforms that are traditionally used on a site to set-out the earthworks.

Alternatively, the system can be used to produce a plan of "isopachytes". These are lines which connect points of equal depth of cut or fill. They therefore identify the location and depth of cut and fill areas, with the zero isopachyte indicating the boundary between cut and fill.

On site, a plan showing isopachytes is extremely useful as an aid to understanding the extent and amount of the required earthworks. The isopachytes show, at any one point, how much material is to be removed or added and have been found to greatly assist the control of earthmoving on a site.

13.6.3 Drainage

Introduction

The installation of an effective drainage system is a crucial element in the remodelling of a landform and is needed to:

- prevent erosion of spoil and/or capping materials;
- reduce the amount of water penetrating areas of mine spoil;
- prevent unwanted ingress of water into mine workings;
- prevent the build-up of water within spoil heaps;
- prevent the migration of silt and contaminants to adjacent land and watercourses both during and after the works;
- aid vegetation establishment in areas susceptible to waterlogging;
- prevent flooding.

The appropriate measures for a site will depend primarily on the local climate, the water regime of the surroundings, the materials on site and the proposed topography, surface finish and after-use.

It is important that drainage measures are designed not only according to technical criteria but also with their visual impact in mind, since they can be very intrusive. For example, lined concrete channels are extremely prominent, especially in hilly terrain. Open channels of large dimensions can also present physical obstructions to movement by people and animals.

In designing drainage the opportunity can also be taken to incorporate wetlands to increase ecological diversity and also to assist in pollution control (see Section 12.5.3).

The following sections describe the types of drainage works usually necessary and discuss design considerations.

Cut-off drainage

Cut-off drainage is provided to intercept surface water arriving above areas of spoil, waste or contaminated materials, and to convey the water safely to the outlet drainage system.

Temporary ditches

Temporary ditches are provided prior to earthworks to intercept surface water and sediment and, if necessary, to convey the water to a treatment unit prior to discharge to the outlet drainage system.

Field drainage

Field drainage may be required in restored areas to assist in the removal of surplus groundwater so as to prevent waterlogging.

Permanent drainage

The function of a permanent drainage system is to intercept surface water run-off or groundwater and convey it to an outfall. The system may also convey existing watercourses across the site. Where permanent drainage is to be installed, the following should be taken into account:

- the effect of a reclaimed site on the downstream watercourses to which the site contributes - in most cases, there will be an increase in peak flow rates immediately downstream of the reclaimed site due to a more efficient drainage system, which has a more rapid response time to short duration, high intensity storms. The effect may be negligible where the site is part of a much larger catchment. However, for a smaller catchment, the capacity of bridges and culverts to receive these additional flows must be evaluated. In some cases, flood attenuation measures may be required, for example soakaways, balancing ponds or flood plains;
- flood flow calculations - various methods have been developed to calculate flood flows resulting from rain falling on a catchment. The application of one method, the Rational Method of Flood Estimation to a reclamation scheme is described in Box 13.10;
- drainage layout - will depend on the proposed landform, the future use of the site and pollution considerations. Both pipes and ditched systems may be employed at the same site. The principal characteristics of the two systems are compared in Box 13.11;
- construction material - care should be taken to ensure that the materials used in the construction of drainage systems blend in with the reclamation scheme finish. Grassed channels or stone faced channels are the least obtrusive, however the former require more maintenance than lined channels and the latter can be costly;

Box 13.10: Factors used in calculating peak run-off in the Rational Method of Flood Estimation[173] and their application to a reclaimed site

When calculating run-off for a reclaimed site and for small catchments of which the site forms a significant part, the Rational Method of Flood Estimation can be used. This gives the peak rate of run-off directly from the catchment area, rainfall intensity and run-off coefficient.

Catchment area

Catchment areas may be obtained from contoured maps. Care must be taken to ensure that leats and underground connections between catchments are taken into account in calculating catchment areas.

Rainfall intensity

For a particular site, the rainfall intensity depends on the storm duration and return period. For a low-risk rural site, a two year design return period would be reasonable. Where there is a risk of flooding to properties, a higher standard of protection would be required.

The consequences of a flood event more extreme than the design event should be considered. This is particularly so in remote areas where meteorological and other data for the site in question may not be reliable. Measures to deal with greater than design event flows include techniques such as reinforcing grassed areas adjacent to channels with geotextile to prevent erosion.

Run-off coefficient

The run-off coefficient is the percentage of rainfall on the catchment which appears as surface run-off in the storm drainage system.

The permeability of the surface material is the main factor determining the run-off coefficient and may vary from 60% for rapidly draining soils to 90% for heavy soils or 100% for surfaced areas.

In choosing a run-off coefficient, it must be remembered that maximum run-off may occur following earthworks and before vegetation establishment. This is the most vulnerable period in terms of soil erosion. The longer vegetation is likely to take to establish, the more weight must be given to this consideration.

Where a membrane or impermeable layer is used in a capping treatment a higher run-off coefficient than usual for the covering material would be appropriate.

- existing drainage systems - historically, mining engineers sometimes constructed elaborate systems of water supply and drainage to service their mines. Some of these still operate and some are redundant. These systems should not be ignored during reclamation schemes and the opportunity should be taken to use them if appropriate.

Box 13.11: Comparison of ditched and piped drainage systems

Ditched systems

Advantages

- economical;
- if constructed along a site boundary they also provide site security;
- provide storage for flood water - this is particularly useful if the outlet to the system is of limited capacity;
- flexible - can be easily enlarged or converted to a piped system;
- can be laid to slacker gradients than piped systems;
- if unlined can act as soakaways, so reducing flow at the outlet.

Disadvantages

- require regular maintenance and are prone to erosion;
- large ditches can be dangerous and restrict mobility around a site;
- need to be laid at slack gradients so if steep falls are required cascades or weirs have to be provided;
- can be visually intrusive.

Piped systems

Advantages

- access around the site is not impeded;
- low maintenance;
- long life;
- multifunctional.

Disadvantages

- limited capacity;
- high cost;
- provide limited storage for flood water;
- not as flexible as ditched systems;
- may become blocked;
- inlets and catchpits require regular maintenance.

Reservoirs and lagoons

Both coal and steel sites may contain ponds, lagoons or larger bodies of open water such as reservoirs. A body of water provided for the coal or steel processing operations may be considered a significant part of the industrial heritage of the site and, if appropriate to the proposed after-use, may be retained.

However an open body of water is potentially very dangerous if raised above the general ground level. Unless it has been regularly maintained, which is most unlikely on abandoned sites, embankments and hydraulic structures may well be in a poor state of repair.

The defects of a dam, for instance, may be such that the cost of repair cannot be justified. However there may be considerably more work and expense involved in abandoning a reservoir than merely taking off the outlet valves or cutting a slot through the dam wall. Sediment is a major hazard when exposed in the reservoir basin and its erosion into a downstream watercourse can cause serious water quality problems.

A reservoir may have provided considerable attenuation to flood flows. A loss of attenuation after breaching may require the enlargement of culverts and watercourses downstream.

Water treatment

During reclamation works polluted water may arise after rainfall and this will have to be dealt with. Drainage works prior to the commencement of earthmoving should aim to minimise the production of polluted water, and temporary treatment facilities may be needed.

Where consents are required to discharge water from the site, stringent water quality standards must be met and treatment systems may need to be devised in order to meet these standards. Further details of such treatments are given in Section 12.5.

13.6.4 Erosion control and stability

Newly created landforms are especially sensitive to erosion and Section 13.6.3 explains the need for temporary drainage measures to counteract this problem. Once a slope is vegetated, surface stability is normally secured. There is therefore some urgency to establish vegetation. However, there is a complex interaction between vegetation, soil, climate and the activities of humans, animals or machines, as illustrated in Figure 13.4.

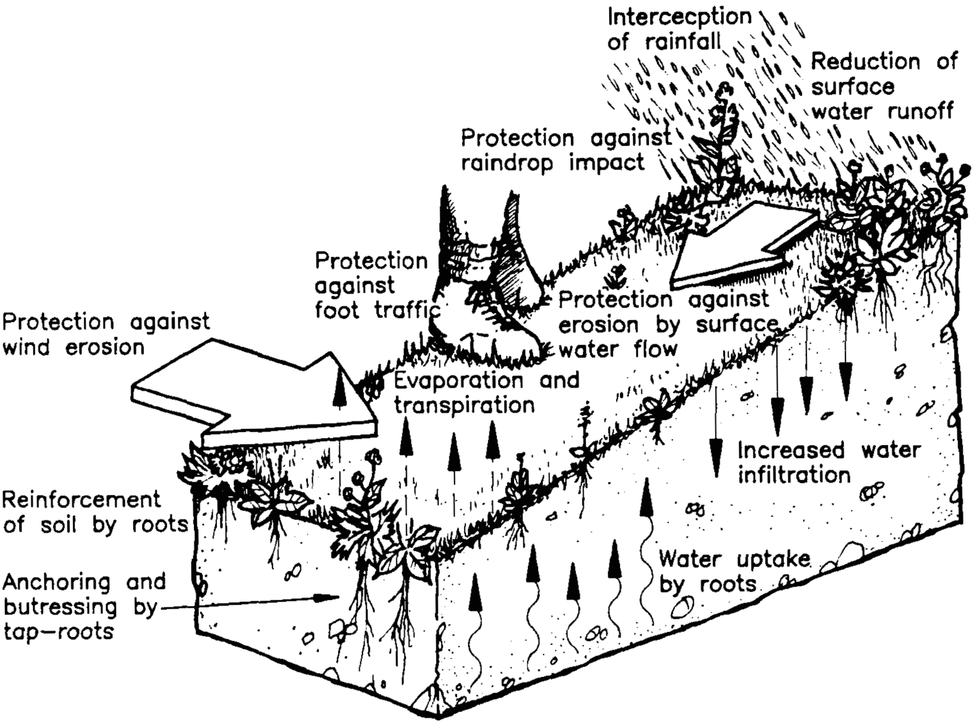


Figure 13.4: Some influences of vegetation on the soil (from CIRIA Book 10, Use of vegetation in civil engineering, 1990[57])

13.6.5 Slope gradients

The gradient of any sloping area is important in relation to:

- how it is created;
- drainage provision and erosion control;
- stability;
- after-use;
- maintenance.

The design team should be aware of the capabilities and limitations of available earthmoving equipment *e.g.* maximum operating angles, turning circles.

For drainage and erosion control, the theoretical optimum gradient of a newly created slope is that at which it will drain naturally without erosion of soil particles. This slope is frequently in the order of 1 in 40 or 1 in 50 for soils and colliery spoil. However, the necessary gradient is dictated in practice by the after-use of the site or by limitations on land-take for the purpose of spreading out spoil materials. These parameters can lead to a need for artificial drainage measures on sites with very shallow slopes, or a requirement for drainage devices to minimise erosion on steeper slopes. Gradients of more than 1 in 3 should be avoided if possible in highly erodible materials. If avoidance of such gradients is not possible the surface should be treated by special stabilisation techniques, such as the use of geotextiles to resist erosion until vegetation is established. A more economical solution is the application of contoured or angled ripping across slopes.

Box 13.6 has referred to the different engineering characteristics of colliery spoil and slags. Colliery spoil should be regarded as being a highly erodible material and slags as being a much lower risk in terms of their susceptibility to erosion.

The slope limitations of various after-uses are described in Box 13.12 and for maintenance procedures in Box 13.13.

13.6.6 Aesthetics

The design team should strive to produce a result which looks right as well as one that functions well. The aesthetics of design is a specialist area which requires training and experience to be fully appreciated.

Spoil heaps are typically very prominent features in the landscape, but this does not necessarily mean they have a negative visual impact. Neither are they necessarily the only or the most obtrusive elements of a derelict site (see Section 13.2). If remodelling of spoil heaps is proposed for visual reasons only, it is important that careful consideration is given to the rationale behind the proposals.

In remodelling the landform of a derelict site, attention should be paid to the characteristics of its surroundings. Blending of landform, surface finish and materials with those of the surrounding area will help considerably to minimise the visual impact.

With a naturalistic landform design (see Section 13.3.2), blending with the surroundings may be more achievable than with an artificial design. In the latter case, screening or disguising the new landform with tree and shrub planting may be the only way to ensure minimum impact. Vegetation can also be used to reduce the impact of tips which are not being remodelled (see Box 13.4). In all cases, new vegetation schemes must be designed with care to ensure that they reduce impact rather than accentuating or adding undesirable characteristics.

The same care is needed with other features of a new landform, especially drainage and boundaries, which if insensitively designed, will draw attention to the site and can be seriously intrusive themselves.

Box 13.12: Slope design for after-use

Angles of slope are critical in all landform design. Existing slopes may be standing at 1 in 2, 1 in 1½, or in extreme cases at 1:1. The gradients to which they must be lowered will depend upon the use to which the land is to be put.

Industrial areas call for very careful consideration since whilst large flat areas require minimal earthworks under a building, flat areas are extremely difficult to drain because of the minimum gradients called for in drainage design. A general slope of 1 in 100 in one direction, or in two directions at right angles to each other, is a reasonable compromise on sites extending to about 5 ha. when the final layout of the development is unknown. For larger sites, gradients of 1 in 150 to 1 in 100 in one direction ease the problems of drainage.

This gradient allows the site to be drained easily by means of land drains or open channels and this is an important element in providing an immediate cover of grass which serves as a control to soil erosion and presents a reasonably attractive site to developers and local residents.

If a layout can be determined for the development, then areas for buildings, car parks, highways and landscaping can be provided with appropriate ground profiles even if development will not take place until some time in the future.

Sports pitches should be steeper than 1 in 150 otherwise they will not drain properly, and must not be so steep as to interfere with play. 1 in 80 is acceptable for association football. **Casual walking** is pleasant on slopes up to about 1 in 8, but people tend to take a winding route to ease the slope on anything steeper than 1 in 10.

If an area is to be planted with **woodland**, a minimum slope of 1 in 10 is advised. Thus, if a site is flatter than this overall, a 'ridge and furrow' landform is recommended with the sides of the ridges sloping at 1 in 10.

Typical gradients for some after-uses with specific requirements are as follows:[143]

Sports pitches	1 in 40 (1·5°) across line of play 1 in 80 (0·7°) along line of play.
Dry ski-slope	c 1 in 4 (14°-17°)
Grass skiing	c 1 in 5 (11°)
Watersports (launching)	1 in 8 (7°)
Amenity woodland	1 in 10 (6°) to 1 in 2 (27°)
Water bodies	(margin) up to 1 in 10 (6°) - for safety reasons and for plants/wildfowl

Box 13.13: Slope design for maintenance and management

If land is to be maintained by grazing, or used for forestry a wide range of slopes are possible. Maintenance of grassed areas by machinery, however, requires care to ensure that working gradients are not exceeded. Safe limits for tractors vary according to:

- the type of tractor;
- the equipment attached to the tractor;
- whether the ground is bare or vegetated (grassed slopes can be much more dangerous than bare soil);
- direction of travel;
- weather conditions;
- the condition of the grass.

As a result of the above, it is possible to use a tractor on slopes of around 1 in 2 in the right circumstances, but at other times 1 in 7 can be hazardous.

The maximum slope for the safe use of a pedestrian grass mower is 1 in 3.

Whilst shallow slopes are easier and safer to maintain, landform design should not aim to avoid steep gradients altogether. In some cases such gradients will enhance the scheme's visual interest. Maintenance problems on steep slopes can be reduced by creating areas which require less management input e.g. woodland, grazed grassland.

Further factors to consider in order to minimise the visual impact of remodelled landforms are given in Box 13.14.

13.6.7 Microclimate

Proposals for remodelling of landforms should aim to improve or at least maintain the micro-climatic conditions in and around the site. Care should be taken to avoid inadvertent effects such as wind funnelling. The design team should also be aware of possibilities such as reducing the sheltering effect of a tip when it is remodelled. Some aspects of microclimate are described in Box 13.15.

Box 13.14: Reducing the visual impact of spoil heaps

In the remodelling of a tip, the following additional factors should be considered so as to maximise the reduction in visual impact:

- a landform seen in silhouette is more prominent than if seen against a landscape background;
- the height of a tip is more noticeable than the bulk, so reducing height is likely to reduce visual impact. This need not involve a large proportion of the volume of a tip. A long, low bulk is likely to be more visually acceptable than a tall, severe landform;
- removal of harsh angles and straight lines in a tip should be a priority;
- straight lines, even slopes and flat surfaces are very prominent, providing strong visual lines to form and bulk. Curved lines and varying gradients are less noticeable and less obtrusive;
- spreading spoil away from an observer reduces the apparent bulk by foreshortening;
- large volumes can be placed unseen behind a false summit, where a landform is viewed from below.

13.6.8 Materials handling

Tipped materials on abandoned coal or steel sites can vary from burning colliery spoil, to fused masses of smelter waste, to saturated sludges. The nature of the waste materials has a major effect on the cost of moving them and the options for treating them.

As a general principle, for reasons of economy, double handling should be avoided and haul routes should be as short as possible.

Excavation into a burning tip creates particular difficulties and is dealt with in Section 7.5.

Box 13.15: Some aspects of microclimate

Landform influences micro-climate by affecting air-flow and by receiving varying amounts of solar radiation, due to variation in aspect and surface reflectivity. Waste tips influence the wind and temperature conditions of their surroundings and can affect air quality in terms of quantity and distribution of gas emissions and dust. They can also provide a baffle against noise emissions.

In a largely flat landscape, a tip, depending upon its shape and size, forms an obstacle for the airstream and weaker air currents circulate round it. When the wind speed increases on its windward side and on its flanks, moderate and strong winds flow over it. On the leeward side, there is first formed a zone of weaker air movements and this is followed further to the lee side by a zone of stronger, more squally winds blowing in irregular directions. These overflow winds, known as the lee effect, cause increased air movement in the lee of the tip.

A planted tip, as a self-contained wooded area, causes a vertical exchange of air masses and also the surface of the canopy causes air turbulence.

Aspect, slope, colour and vegetation cover influence the temperature of a tip surface and the air above it. South-facing slopes of unvegetated, dark shales can reach 60°C or higher in sunny, windless conditions. Such extremes of temperature are gradually reduced as vegetation cover becomes established.[33]

An interesting consequence of the conditions that can be found on colliery spoil heaps is that they can be suitable for growing vines. The suitability of tips for viticulture is partly due to the dry, stoney conditions which vines like, but also because the dark material is a good absorber of solar energy and this is given off again, warming the air above the surface. Thus, in Belgium, the temperature at the summit of a spoil heap has been found, at all times of year, to be 2-5°C higher than at the foot.[193] Slopes of 25-45°, at the latitudes found in Belgium, are optimal for reception of solar energy.

Another particular problem arises from lagoons, used to settle out waste from coal washing plants. These lagoons can be found within spoil heaps, having been tipped over after falling into disuse. It may be necessary to use a drag-line excavator to deal with lagoon sediments, which tend to remain in a saturated or super-saturated condition (see Section 8.3.4).

Where material is being placed in an area which will be vegetated, care should be taken to avoid handling the material in very wet conditions, and trafficking over the area by earthworks plant should be minimised. If trafficking is unavoidable, the placed material should be cultivated before placement of the next layer, to reduce compaction (see Tables 5.6 and 5.7).

If topsoil or sub-soil exist on site these materials should be conserved for re-use. Natural soils are a valuable resource which may not be available in large quantities. It is especially important to take care with the handling and storage of topsoil, since irreparable damage can be done to the soil, in terms of potential for plant growth.

Box 13.16 gives more information on soil handling practices and Figure 13.5 illustrates techniques for soil spreading using heavy machinery, which avoids excessive surface compaction. Section 14.4.3 discusses the advantages and disadvantages of using natural soils in reclamation work.

13.6.9 Compaction

When waste materials are moved they can be placed loose or they can be compacted. If placed in layers of suitable thickness and compacted to the appropriate degree, stable slopes can be created where they would otherwise not be stable, and ground can be created which has adequate bearing capacity and is consistent enough to carry buildings. Information on alternative techniques of ground improvement is provided in Section 13.6.10.

Invariably in the past, spoil heaps were created by loose tipping. In order to create a stable landform it may therefore be necessary to move, place and compact most or all of the material in a tip.

Where vegetation is to be established, compaction should be avoided, but where it is unavoidable or already existing, on haul routes for example, compaction must be relieved by ripping as part of the soil cultivation process (see Section 14.4.2).

Box 13.16: Soil handling, soil quality and vegetation establishment[57]

The selection, handling and treatment of soils which are to be used within the potential root zone of the vegetation, say within 1m of the final ground surface, should take account of:

- their potential as a medium for plant growth;
- the construction of a soil profile;
- the relationship between soil layers.

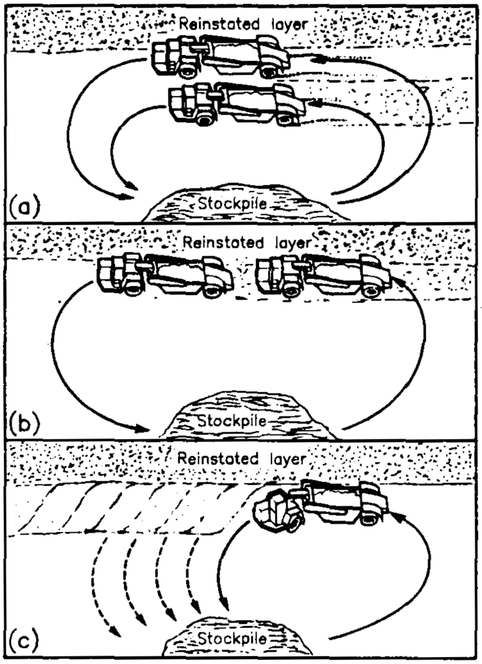
Irreparable damage can be done, in terms of potential for plant growth, if a soil is handled incorrectly. The problems to avoid are:

- stockpiling in such a way that the natural aerobic soil organisms are killed;
- destroying the existing soil structure;
- compacting soil to excessive densities that reduce water infiltration and inhibit root growth.

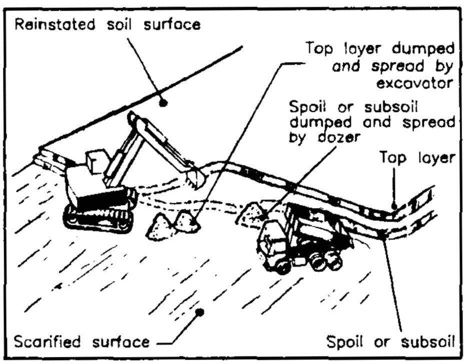
When moving large quantities of soil it is usual to employ the most cost-effective, and sometimes the largest, machinery available. For engineering purposes, the compaction effects of large machinery are beneficial, but tracking over surface soils with machinery which imposes a high ground pressure destroys soil structure and produces conditions which are very inhospitable to plant growth. The cost of precautions to avoid damage to soil may be offset against the benefits of improved plant establishment and growth. However the conflict between soil compaction for stability and looseness to permit plant growth is one which has to be considered carefully in each situation.

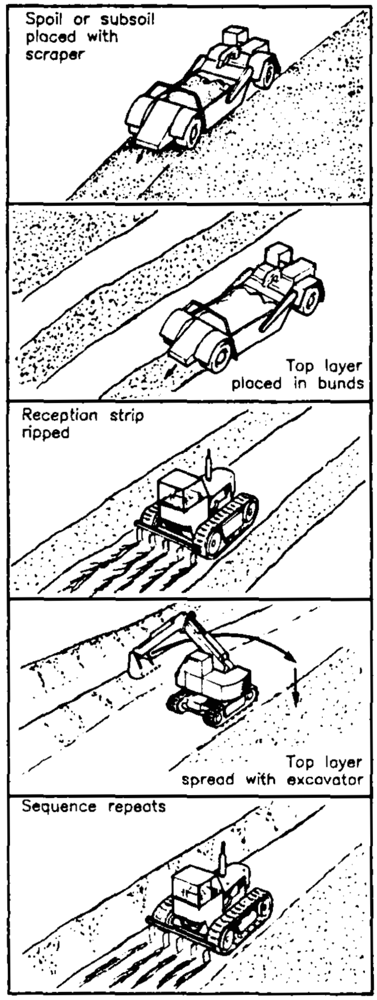
Damaged soil may never be fully restored by cultivation, but there are a number of practices which, if followed, will reduce the extent of soil damage:

- where possible, excavators and dumpers rather than scrapers should be used to move soil;
- double handling should be avoided as much as possible;
- stockpiles, where they are necessary, should be low and not heavily compacted but graded to shed rainfall. Long-term stockpiles should be seeded to avoid erosion;
- handling of soil should be strictly controlled according to soil moisture conditions. Similar restrictions should apply to tracking over existing or respread soils, when wheel damage can be extensive. Tracking should only be allowed over a soil the strength of which, as measured with a pocket penetrometer, is greater than the ground pressure of the machinery involved;
- indiscriminate tracking by heavy earthmoving machinery over surfaces of existing or spread soil should be avoided. Vehicles should keep to the same wheel-tracks as much as possible, so confining the damage. These wheel tracks can be specially treated later by deep cultivation;
- the temptation to travel repeatedly over an area of spread soil to grade off the surface should be resisted, since this will only produce a smooth, compacted soil surface which will make vegetation establishment difficult.



Surface reinstatement with earth scrapers:
(a) indiscriminate running over the site;
(b) improved method keeping to wheel tracks;
(c) improved method with no running over the reinstated surface. Ripping of intermediate layers will be necessary to relieve heavy compaction caused by the earth scraper.





Reinstatement of topsoil and subsoil layers by dumper and excavator. Soil material is dumped on the fill surface and moved to its final position by excavator or dozer. There is no running over the reinstated surface.

These techniques are appropriate in the final stages of an earth moving operation for spreading any soil materials which will form the top 1m growing layer. They apply equally to topsoil, subsoil, and soil substitutes.

Figure 13.5: Soil spreading techniques which avoid excessive compaction (from CIRIA Book 10, Use of vegetation in civil engineering, 1990[57])

Loosening of surface layers to enable vegetation to establish and thrive does however encourage penetration by water. Water penetration can be a problem on very flat areas, where natural drainage is impeded, and therefore designs should avoid such circumstances by introducing minimum gradients appropriate for the intended development. For reasons of stability, penetration of water into some tips is also to be discouraged (see Section 6.4).

13.6.10 Ground improvement

Derelict coal and steel sites may contain areas of filled ground which are very variable in nature and consistency and may be unsuitable for building on without special treatment. Details of ground improvement techniques are contained in Box 13.17. However existing fill may sometimes be sufficiently compact for building construction without the need for further treatment.

Consideration should be given to the constraints caused by the presence of existing buried foundations, flues and tanks. The proposed layout of roads, utility services and building plots should be designed to minimise the potential problems from underground obstructions, and in some cases old foundations and other buried obstructions will need to be removed. In order to reduce costs, certain parts of the site may need to be designated as landscaped areas or hard-standing, requiring minimal or no disturbance of buried obstructions.

A solution which is sometimes adopted on reclamation sites involving poor ground conditions is to provide a compacted mattress of suitable material at least 1.5m thick over the whole of the development area, using inert slag, colliery spoil or crushed demolition materials. This approach provides flexibility in the planning of the proposed development and overcomes problems of hard ground due to old foundations or areas of hard tipped materials. Any old basements or other underground voids should be backfilled using suitable granular material compacted in layers.

Box 13.17: Ground improvement techniques[53]

Dynamic compaction

Deep compaction of the fill is effected by the repeated dropping of a heavy weight using a crane e.g. a 15 tonne weight dropped from a height of up to 20m, on a grid pattern.

Treatment may be carried out using high energy impacts for the primary and secondary grids, the latter being offset from the former. Craters formed by the impacts are filled using earthmoving equipment and a second stage of more uniform treatment is carried out using a reduced drop height.

An alternative method of treatment for shallower fills is to use a rapid impact compactor, which involves dropping a 7 tonne weight from a height of 1.2m onto a circular plate.

Vibro techniques

Vibro techniques involve the compaction of granular soils or the formation of stone columns using a vibrating cylindrical poker suspended from a crane. The poker may be 300mm to 450mm diameter and can weigh up to 4 tonnes. Treatment depths of around 6m are typical, but depths up to 30m have been achieved. The poker penetrates the ground as a result of the vibratory action assisted by flushing jets in the nose cone and sides. Compressed air is generally used for flushing, although water may sometimes be employed.

Vibro treatment is carried out on a grid pattern, using closer grid spacings where higher bearing capacities are required e.g. beneath pad foundations or edge beams.

'Vibrocompaction' is the term generally used to describe the densification of granular soils using vibro techniques. Additional material may be introduced from the top of the hole as part of the compaction process. An alternative in unstable ground is to use the bottom feed process whereby stone is introduced directly from the tip of the poker via a feed pipe.

'Vibrated stone columns' is the term used for the stone columns introduced and compacted by the vibro process in order to improve the bearing capacity.

Preloading

Preloading involves over-consolidation of the fill by temporary surcharging to improve the bearing capacity prior to construction taking place. Surcharging is usually carried out using several metres of fill material placed using earthmoving equipment and left *in situ* over a period of two to three months.

Excavation and recompaction

This method involves the treatment of loose granular fill material by excavation and recompaction in thin layers under controlled conditions using conventional earthmoving equipment.

Areas of biodegradable fill materials may need to be removed and replaced with suitable inert fill prior to development, in order to overcome possible landfill gas migration and ground subsidence.

Upon completion of the reclamation works, geotechnical investigations will be necessary to provide information for the design of building foundations and road formations. Special foundations may be required to overcome poor or variable ground conditions, possible subsidence or differential settlement.

13.6.11 Volumes

Earthworks design necessarily involves calculation of volumes of material. The principles, advantages and disadvantages of various methods are outlined in Box 13.7 in Section 13.5.

When an old colliery spoil heap of loosely tipped material is moved and then heavily compacted to provide land which will support buildings, and highways for example, there is a decrease in volume by a factor of about 10%. This reduction factor has to be taken into account when designing reclamation works that involve moving spoil material.

Where a balance of cut and fill is not achieved in the design, it will be necessary either to import material on to the site to complete the designed landform, or alternatively to export the surplus off the site.

Despite calculating a balance of cut and fill at the design stage, there is nevertheless likely to be an imbalance in the earthworks when the scheme is implemented. This imbalance can be due to a number of reasons, such as the actual reduction factor not being quite the same as that predicted, and amendments to the landform design during reclamation work. It is good practice therefore to include in the scheme a balancing area where the final levels can be varied without any detrimental consequence for the overall aims of the project.

13.6.12 Timing

The timing of the implementation of a reclamation scheme may be important because of:

- seasonal differences in the weather;
- the affect of weather on ground conditions;
- the need to prepare a site for vegetation establishment;
- community needs;
- financial arrangements.

This was discussed in Section 13.4.5 and in Box 13.6.

13.6.13 Environmental impact

The reclamation of a coal or steel site should reduce its environmental impact, in terms of, for example, air and water pollution and visual intrusion. However, the reclamation process can cause temporary impacts, which should be anticipated and planned for in the design stage. These include:

- noise from earthmoving plant;
- dust raised by machinery and blown onto adjacent areas;
- pollution of watercourses through disturbance of materials;
- increased traffic in the area, especially if bulky materials are imported or exported;
- disposal of contaminated materials, if taken off site.

13.6.14 Records

It is in the nature of reclamation work that the results produced on site are frequently not exactly the same as the proposals shown on working drawings. After reclamation has been completed, experience has demonstrated that it is essential to have thorough and precise records and plans of what was actually done in the reclamation scheme. These will be invaluable:

- if any problems arise, such as accidental exposure of encapsulated contaminated material;
- if there is a requirement in the future to change the landform;
- in the post-reclamation use, development and management of the site.

It is therefore advisable to ensure that an 'as-built' survey is carried out on completion of reclamation and that an archive is set up to record the details of what was done. More information on site records is given in Section 15.4.3.