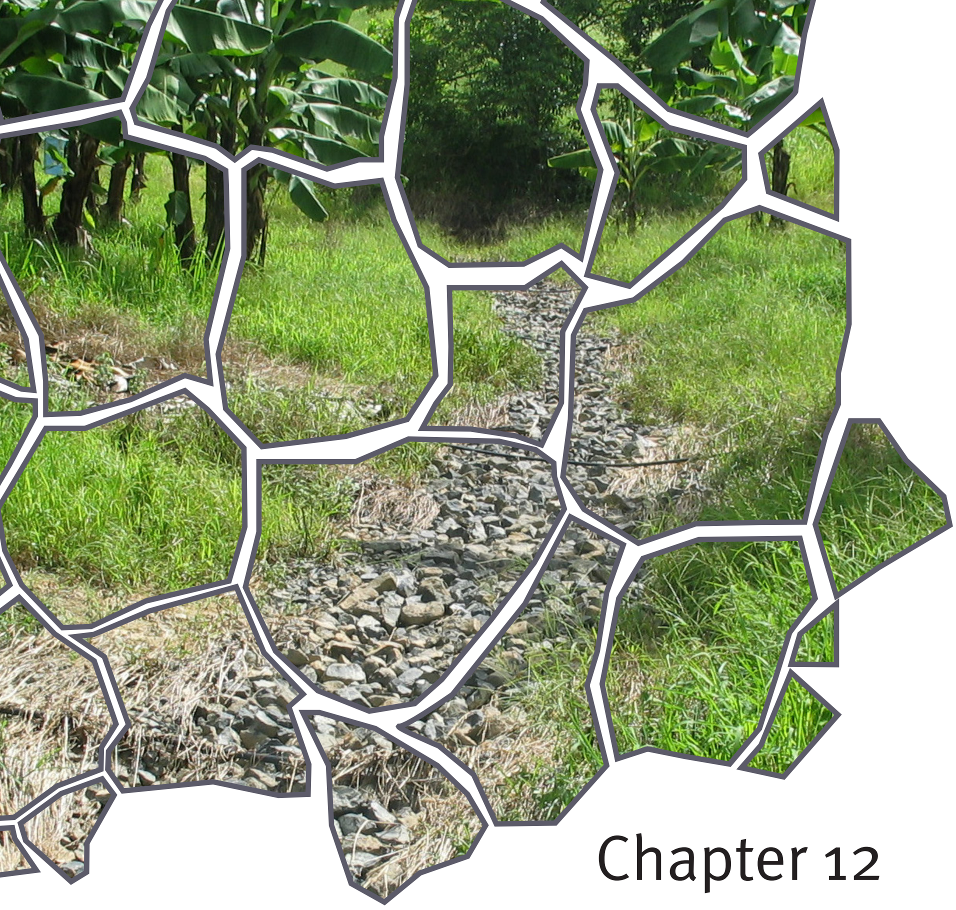


Chapter 12

Soil conservation in horticulture

Key points

- Horticulture is a significant part of agriculture in Queensland. Horticultural land is valuable and can be vulnerable to erosion.
- It is important to plan carefully before laying out a property for horticulture, to avoid creating erosion or increasing existing erosion problems. Effective planning should take into account the existing environmental conditions of the property and its surrounds (such as the soil type, topography and climate), as well as the access, irrigation and drainage needs of the enterprise.
- Horticulture is an intensive land use, often involving frequent cultivation and reforming of the soil surface, such as with mounding or terracing. It is critical that ground cover be maintained to prevent erosion occurring. Crop type, crop management system and any land surface modification will affect the best way of maintaining ground cover. Ground cover may involve artificial surfaces such as plastic sheeting or natural materials such as mulches or cover crops.
- Most horticultural properties are irrigated, many are in high-rainfall areas, and some are on steep slopes. Any one of these factors has the potential to generate runoff that can be damaging to soil on the property as well as to the environment downstream. Effectively managing runoff on site will ensure that water leaving the property is suitable for reintroduction to the environment. Runoff on horticultural properties is commonly managed by ensuring there is effective ground cover, and with earthworks such as mounds, contour banks or contour drains and sediment traps.

Contents

Glossary

bagasse: dry fibrous residue left after juice has been extracted by crushing of sugarcane stalks.

capacitance probe: a device for measuring soil moisture conditions that uses capacitance as detected from probes placed within PVC tubes buried to various depths.

coulter: a tillage tool that cuts plant material and soil ahead of another tool. The most common kind is a disc coulter.

cover crop: a temporary vegetative cover which is grown to protect the soil and to aid establishment of plants, particularly those that are slow to establish.

ferrosol: a soil with a B2 horizon which is high in free iron oxide, and which lacks strong texture contrast between A and B horizons.

field capacity: the amount of water, expressed as a percentage of the oven dry weight of the soil, held in a soil after any excess has drained away following saturation.

geotextile: permeable fabrics, typically made from synthetic materials, which when used in association with soil have the ability to separate, filter, reinforce, protect or drain.

green manure: a crop grown primarily to provide a source of organic matter to the soil and normally incorporated into the surface soil by mechanical means.

Manning's n: a measure of resistance to flow or retardance in a channel; the greater the resistance the higher the retardance. It is calculated using the Manning formula and has the symbol 'n'. Retardance is influenced by the physical roughness of the internal surface of the channel (e.g. the vegetation that lines it), channel cross-section, alignment and obstructions.

mill mud: fine mixture of organic and inorganic materials remaining after sugarcane juice has been clarified and filtered in a sugar mill; used by some growers as a soil nutrient and organic matter supplement.

ratoon crop: a new crop of sugarcane produced from shoots sprouting from the stubble of the previous crop. Generally only two or three ratoons can be grown before the plants lose vigour and need to be fully removed and new plants established.

self-mulching: the characteristic of a well-aggregated, moderate to high clay content soil in which the surface layer forms a shallow mulch of soil aggregates when dry. Aggregation is maintained largely as a response of the clay minerals present to the natural processes of wetting and drying.

sodicity: the amount of exchangeable sodium (ESP) in a soil. Excess exchangeable sodium adversely affects soil stability, plant growth and/or land use. A soil with more than 15% ESP is considered strongly sodic.

soil erodibility: susceptibility (of a soil type, or part of the landscape) to erosion.

tensiometer: an instrument designed to measure the tension or suction that plants' roots must exert to extract water from the soil. This tension is a direct measure of the availability of water to a plant.

wilting point, or permanent wilting point: is approximately the driest water content achievable by plant extraction. While it differs between soil types, it does not differentiate between various plants' abilities to extract water from a soil. Wilting point is measured as the theoretical lower limit of plant available water and is defined by the parameter LL15 (15 Bar). It can be measured in the laboratory equilibrating the soil to 1500 kPa (15 Bar) suction.

12.1 Introduction

In value, Queensland's horticulture is the second-largest agricultural sector, after beef. Queensland farms in 2011 produced almost $2 billion worth of fruit and vegetables, making the state the largest producer of vegetables in Australia and the second-largest producer of fruit, behind Victoria (State of Queensland 2013). Inputs to—and returns from—horticulture are characteristically high per unit of area compared with other forms of agriculture. Horticulture is then often referred to as an 'intensive' land use, distinguishing it from broadacre cropping which is often referred to as an 'extensive' land use.

Around 140 000 hectares of Queensland is used for horticulture (State of Queensland 2013). This land is concentrated primarily along the east coast from the Wet Tropics to the New South Wales border, and inland including the Granite Belt, Lockyer and Fassifern Valleys, Atherton Tableland, Chinchilla, St George, South Burnett, Bundaberg, Mundubbera, Gayndah and Emerald areas. Horticulture requires land with highly specialised characteristics in terms of climate, soil and access to water, along with proximity to labour, transport and markets. Most horticultural crops are grown under irrigation. Irrigation water is sourced from watercourses, 'harvested' overland runoff or ground water. Horticultural land commands prices higher than that of other forms of agriculture.

A very diverse range of horticultural crops are grown in Queensland. These can be categorised as follows:

- Small crops (mostly annual) include vegetables (cabbage, broccoli, beans, potatoes, onions and pumpkins), salad (lettuce and capsicums), short-rotation fruit crops (such as tomatoes, melons and strawberries), ornamentals (cut flowers, nursery plants), and pharmaceuticals. Generally several of these are grown in rotation on a horticultural property.
- Plantation crops include pineapples, papaws, bananas, coffee, tea and duboisia (corkwood). Plantation crops generally require specialised infrastructure (such as trellising) and/or processing facilities and are usually grown exclusively.
- Tree and vine crops include citrus, avocados, macadamias, mangoes, passionfruit, apples, pears, grapes, stone fruit, custard apples, persimmons, olives and a wide range of exotic tropical fruits.

High-intensity rainfall is a characteristic of Queensland's climate, and this increases the risk of serious erosion if soil is not protected. Much of Queensland's horticulture, particularly vegetables, is located on alluvial flats where the erosion risk is less, provided these areas are not subject to erosive flooding during major runoff events. However, some crops—particularly perennial tree crops and plantations—are often located on steep slopes and foothills that are vulnerable to water erosion. Wind erosion is not a significant problem in Queensland's cropping lands because cropping is mostly practised on clay soils that are coarsely tilled to form large aggregates that resist disturbance by wind. Wind erosion may be a concern where cropping occurs on light-textured soils such as sands and sandy loams but these areas are comparatively limited in Queensland.

This chapter provides only general information for controlling erosion in horticultural crops. Because horticultural crops, soils, climates and farming systems vary so much across Queensland, it is not possible to provide precise guidelines (e.g. relating to sizes of furrows, beds, mounds and the lengths and gradients of interception structures) for all situations.

This chapter does not use formal design methods, as used in some earlier chapters of these guidelines, because most experienced horticulturalists use layouts implemented by 'eye' after making a number of visual observations. However, detailed design methods such as those outlined in earlier chapters should be considered.

Key principles to be considered when implementing erosion control measures in horticultural production are:

- planning—to ensure that the land selected is suitable and can be managed appropriately for the intended use,
- maximising ground cover, and
- managing overland flows of water.

Each of these principles is dealt with separately in the following sections.

12.2 Planning

The key objective in planning for a horticultural property is to ensure that the chosen crops are suited to the characteristics of the selected site and that the land is managed in an efficient and sustainable manner with minimal off-site environmental impact. A well-planned horticultural property that employs an appropriate range of soil conservation measures will provide the following benefits:

- **On-farm benefits:**
  - increased crop production
  - less exposure of crop surface roots to desiccation
  - improved surface and subsurface drainage resulting in improved crop root growth and reduced disease problems
  - increased infiltration of rainfall resulting in reduced irrigation costs
  - reduced loss of topsoil
  - reduced fertiliser loss, and more efficient use of applied fertiliser
  - reduced impacts on water quality of on-farm stored water
  - reduced need for repairs to cultivation areas such as filling in rills or gullies
  - reduced wear and tear on machinery
  - improved in-field access resulting in reduced post-harvest losses, such as from bruising of produce in transit to the packing shed.
- **Off-farm benefits:**
  - reduced impacts on natural environment, including water quality
  - more consistent employment
  - improved scenic amenity
  - improved market access.

Many factors affect the suitability of a site for horticulture and need to be taken into account when planning a horticultural property. The following sections discuss some of these factors, how they influence suitability for horticulture, and how limitations in these factors may be overcome.

12.2.1 Environmental factors

Soil type

A range of different soils are suitable for irrigated horticulture; in general, highly fertile soils will produce high yields with few inputs and hence, higher profits. However, different crop types differ in their sensitivity to or tolerance of different soil characteristics. Many horticultural crops grow best on well drained, light-textured soils but others prefer well-structured, self-mulching, cracking clay soils. Soils can exhibit limitations that restrict productivity of horticultural crops, and the most common ones in Queensland include:

- nutrient deficiency
- presence of rocks and stones
- shallow or impermeable soils
- low water-holding capacity
- pH levels that may affect the availability of nutrients or toxicity of some elements
- low levels of organic matter
- poor drainage
- seasonal hard-setting surface
- salinity
- sodicity.

Intensive crop management, as with horticulture, can make it economically feasible to invest in remedial actions to modify conditions to reduce or remove some of the soil limitations. Examples of such remedial actions, and the limitations they address, include:

- irrigation to address insufficient rainfall, timely application of water, or low water-holding capacity
- fertilisation, addressing nutrient deficiency
- land surface modification, mounds or beds, to increase effective soil depth and improve drainage
- subsurface drainage to reduce waterlogging
- green manure crops and compost to improve organic matter levels
- removal of rock or stone to improve workability
- amendments (e.g. gypsum or lime) to improve soil structure.

Mapping of soils (at scales of 1:25 000 or better) is required when planning for horticulture. However, most of Queensland is mapped at a comparatively coarse scale, >100 000, which will not accurately identify the soils at a specific location and is not suitable for detailed planning. This scale of mapping can be useful in indicating the likely soil types at a location, which in turn may show the suitability of soils in that area for particular crops. A professional soil surveyor can use these broadscale maps as a basis for more detailed mapping in conjunction with air photos or imagery and additional soil sampling. Appendix 2 to these Guidelines describes ways in which this soils information can then be used to classify soil types according to their capability or suitability for different crops.

Other information about soils, land resources, climate, vegetation and land use and management is publicly available in Land Resource Bulletins and Land Management Field Manuals—see 'Other information' at the end of this chapter. The Queensland Agricultural Land Audit (State of Queensland 2013) is another source of information showing potential areas for horticulture.

Landscape and topography

It is important that natural watercourses, including rivers, creeks and wetlands, are retained and not disturbed when cultivating adjacent upland areas. In addition to their environmental values, natural watercourses can be both a source of water and a way to safely collect and convey runoff.

A landscape is made up of a collection of catchments separated by ridge lines from which runoff flows downhill to drainage lines. Upper slopes adjacent to the ridges are generally convex; lower slopes adjacent to drainage lines are generally concave. Convex slopes spread runoff outwards; concave slopes tend to concentrate it.

Slope length is also important. Long slopes allow runoff to concentrate and potentially become more erosive. For a given gradient, the longer the slope, the greater is the runoff volume and flow velocity—hence, the greater the potential for erosion.

A landscape can be referred to as having either an 'even', or a 'complex and broken' topography. Landscapes with even topography characteristically have ridges that are lower, slopes that are flatter, and drainage lines that are further apart and broadly parallel. Landscapes with complex and broken topography have higher ridges, steeper slopes and closely spaced drainage lines of variable direction.

The best way to manage erosion when planning a horticultural property is to design the layout to take into account the natural ridge lines and drainage lines (Figure 12.1). The ridges, or catchment divides, are ideal locations to position roads and tracks. Runoff flowing from a road or track located on a catchment boundary can be relatively simply and safely directed to a drainage line. This can be achieved by having runoff control works constructed on the contour, either diagonal to or directly up and down the slope.

Mounds on which tree crops are grown can be aligned either across the slope or, especially where slopes are short, up and down the slope. Extra care is required when locating structures on or near to the contour, as undesirable bends can be required when these structures cross natural drainage lines. Bends in structures such as mounds or contour banks or drains will affect the workability of the paddock and may impound water and lead to waterlogging.

Figure 12.1: Google Earth image showing a tree mound layout on the Sunshine Coast based on subcatchments

In some southern parts of Queensland, horticultural crops susceptible to damage by frost are grown on small pockets of very steep land that is frost-free and well drained. Apart from the high risk of erosion, other reasons to discourage cultivation on steep slopes are:

- difficulties in implementing effective soil conservation measures
- high risks in safely operating machinery
- difficulties in access by workers and machinery, resulting in higher production costs
- less effective means of applying consistent levels of irrigation water.

As a result, in Queensland, the use of very steep slopes for horticultural cropping purposes has tended to decrease in recent times. Now, vegetable crops are mostly grown on slopes less than 10% and most plantation and tree crops on slopes less than 15%.

In some cases it may be preferable to confine cultivation to the crest of ridges where slopes are generally lower and soils deeper than on the surrounding upper and mid-slopes. Where the land 'shape' is suitable, long blocks running along a ridge may be more practical than blocks running down the slope. Where blocks are located along the ridge, runoff can be periodically diverted before it builds up sufficient volume and velocity to remove topsoil. Where blocks are located on slopes away from the ridge lines, additional works or measures for controlling runoff may be required.

Valley floors and floodplains are ideal locations for horticultural crops because they contain fertile alluvial soils and are close to water supplies for irrigation. Also, these areas are likely to contain natural wetlands that are valuable areas for biodiversity, groundwater recharge or discharge, water purification and supply.

Low-lying valley floors in some regions may not be suitable for some crop types, due to the prevalence of frosts. However, valley floors are usually flat, with a low risk of erosion provided the land is not subject to erosive flooding. Nevertheless the risk of significant erosion from rare, high-level flood events should be assessed. To minimise erosion and the impact of flooding on crops, a buffer of vegetation should exist between the natural watercourse and the production area. Appropriate widths of buffers vary depending on the primary purpose of the buffer—refer to the Wetland management handbook (State of Queensland 2008) for more information.

Aspect

Aspect can influence the period over which plants actively grow and, therefore, their yield. Plant growth may be limited both at high temperatures and at low temperatures. In general, during winter growth will be longer on warmer, northerly slopes where the incidence of frost is reduced. Aspect will also have a major bearing on the exposure of plants to wind (see below). This effect of aspect may be increased or reduced depending on the crop type. Sensitivity to temperature and hence aspect varies between different crop types and varieties depending on their peak growing season.

Orienting crop rows in a north-south direction will increase sunlight exposure to both sides of the plants (the further from the equator, the greater this effect). This will help crops to grow better when conditions are colder and for some—such as mangoes, where flowering is strongly influenced by the amount of sunlight the plant receives—will help to increase fruit set. For some crops, orienting the rows in this way may also help to dry foliage more rapidly after rain, reducing their susceptibility to certain plant diseases.

Other influences on the orientation of rows include drainage requirements, topography, irrigation layouts and types of machinery used.

Climate

Exposure to strong wind can reduce yields from horticultural crops. Wind exposure can increase moisture loss, physically damage leaves, branches, flowers or fruit and may reduce pollination. Strong winds can also uproot crop trees. In Queensland, crops require protection from south-easterly and northerly winds in summer and westerly to south-westerly winds in winter, especially in southern areas. Some crops are more vulnerable to wind damage than others. For instance, crops with large leaves are more susceptible to moisture loss and physical damage than those with small leaves. It may be possible in some instances to compensate for some of the effects of wind. Generally it is not recommended to irrigate with sprays in windy conditions (alternative systems such as trickle or drip being preferred); however, where this is unavoidable, it will be necessary to compensate for the increased rate of moisture loss and reduced efficiency of spray irrigation systems by increasing the amount of water applied.

Shelter belts of trees are commonly used to protect crops from wind. However, trees take many years to grow large enough to provide effective protection from wind. The delay can be reduced by incorporating existing tree belts into windbreaks, if this is possible. In vegetable crops an inter-row planting of a fast-growing annual or perennial cover crop such as forage sorghum may be planted or established at intervals (say, every few rows) before crop planting to provide some protection for newly planted crops (e.g. seedlings) when they are most vulnerable to wind damage, including 'sand blasting'. Alternatively, artificial windbreaks made of mesh materials such as shadecloth may be used. These are expensive but they have become popular because they provide instant protection, are flexible, and require limited maintenance. A new windbreak should be constructed at least 10 m from the edge of the crop to ensure sufficient clearance for machinery access. If the windbreak consists of planted vegetation, this setback will also help to minimise potential loss of crop production through competition with shelterbelt plants for light, nutrients and moisture. In southern parts of the state a 5 m high structure (such as a tree) will cast a 5 m long shadow at midday in June so that in winter, crops very close to the southern side of tree belts may receive no sunlight at all.

12.2.2 Management factors

Access roads and tracks

Horticultural properties require a dense network of access tracks that are usable in both wet and dry conditions. To avoid erosion problems it is critical to integrate these access roads and tracks with the runoff control measures required throughout the property. Uncontrolled runoff will erode access roads, removing gravel surfacing and making them rough, boggy and potentially impassable in wet weather. Rough tracks damage machinery, increase the risk of accidents, increase travel time and damage produce leading to lower market prices. On the other hand, an efficient and well-maintained network of access tracks can provide the following:

- efficient movement throughout the property
- collection and diversion of runoff into natural or constructed waterways
- reduced need to walk up and down the slope when harvesting
- efficient use of large spray equipment where required
- safe access for vehicles, equipment and people.

Roads should preferably be aligned either straight up and down the slope or on the contour. Roads that run up and down the slope provide easy access, allowing harvested crops to be carried across the slope to transport vehicles. However, runoff can concentrate in the wheel ruts or between sealed tyre paths and cause erosion if the roads are not maintained with a suitable surface and with cross-drains. Roads aligned across the slope may have steep batters on the uphill side and can concentrate runoff and cause erosion. Where a network includes roads that are aligned across the slope they should be constructed in either of the following configurations:

- in-sloping roads, with a cross-gradient of not more than 3%, to direct runoff to drains constructed at the foot of the batter then diverted with appropriately spaced cross-drains and safely dispersed downhill with stable natural, or constructed, drains
- out-sloping roads that allow rainfall to flow across the road and continue down the slope. However with these, maintenance can be challenging as even the smallest wheel rut will concentrate runoff.

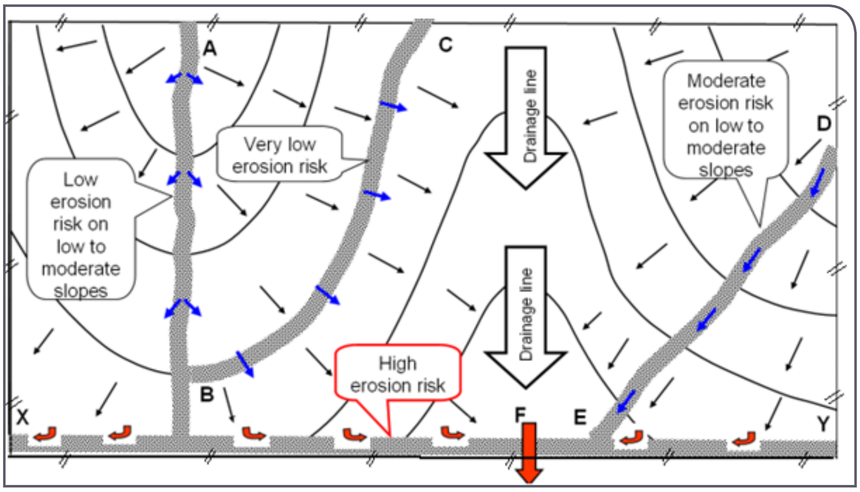
Generally, tracks with infrequent use should be stabilised with vegetation, such as grass or other suitable cover, whilst regularly used tracks where the risk of erosion is high should be surfaced with crushed rock or gravel. Where roads run up and down the slope they should be either grassed (if they can be slashed) or sealed or concreted to protect against erosion. Although sealing tracks is more costly, it has the following advantages:

- provides the added safety of a secure and stable surface
- provides all-weather access for conventional vehicles
- requires less short-term maintenance, although over the long term, maintenance requirements for a sealed track can still be high.

Particular care should be taken when designing access for perennial horticulture properties, such as for banana or pineapple plantations, because they are often located on steep slopes in high-rainfall areas that are erosion-prone. Here, roads and tracks should be located below diversion banks, or parallel and adjacent to drains and waterways (Figure 12.2). Ridge lines (A to B) are ideal locations for access roads and tracks, requiring less maintenance than those in other parts of the landscape. They receive no overland flows and their slopes are usually gentler than other parts in the landscape. They are more likely to remain trafficable in wet conditions and, being elevated, they provide good vantage points to inspect a property.

Another suitable location for tracks or roads is on the contour (B to C) if runoff can be allowed to flow directly across the road. Roads diagonally across a slope (B to F) should be avoided, being more susceptible to erosion because they intercept and concentrate runoff. A safer option may be to align the roads directly up and down a slope (D to E). Although steeper than diagonal alignments, they intercept virtually no overland flow other than that which falls directly on them.

Figure 12.2: Options for locating roads and tracks in hilly country



Wherever tracks are constructed on sloping country they should include whoa-boys—trafficable banks crossing roads at an angle and which empty into a broad, flat dispersal area on the downhill side. Whoa-boys prevent erosion by regularly intercepting runoff that flows down a road and safely dispersing it to the side of the road. See Chapter 14 for specifications for whoa-boys.

Although roads and tracks may be located parallel and adjacent to constructed grassed waterways, avoid locating them in waterways. Roads and tracks constructed within waterways are very likely to erode. Where unavoidable, consideration should be given to concreting the tracked areas.

Regular vehicular traffic along roads and tracks will compact the surface and discourage grass growth, leading to increased amount and rate of runoff. Traffic also creates wheel ruts that concentrate runoff and cause erosion, and may cause water to pond in wet weather, bogging vehicles. Where tracks or roads cross drains or watercourses, the flow in the drain or watercourse should be directed through culverts or pipes; alternatively, the crossing should be at bed level and stabilised with concrete, rock or gravel. Crossing of natural watercourses should be avoided where possible. Where a crossing may have the potential to change hydrology, for example, with culverts or pipes, an approval for a waterway barrier may be required—see ‹www.daf.qld.gov.au/fisheries/habitats/instream-structures-and-fish-passage/waterway-barriers›.

Heavily trafficked roads should be crowned to shed runoff, and use should be made of grassed flat-bottomed table drains to receive and safely dispose of runoff. Roads and tracks that are below normal ground level due to heavy use or inappropriate maintenance are especially at risk of erosion as runoff cannot be shed to the side. Subsurface roads and tracks concentrate runoff and are likely to develop rills or even gullies.

Irrigation

Most horticultural enterprises include the use of irrigation water. Poor irrigation design or management can increase and concentrate runoff leading to erosion. It is important to consider the form of irrigation to be used when planning and implementing soil conservation works. For tree crops, the intended surface and subsurface drainage measures should be thoroughly planned and then properly installed before planting. Once trees are larger, erosion problems are more likely to become apparent when the grass between them loses vigour due to shading and bare soil is exposed. It is much more difficult and expensive to carry out remedial measures at this later stage.

Specialist advice should be sought from a suitably qualified irrigation designer when planning an irrigation system. The irrigation system should be integrated into the farm layout and be compatible with surface drainage systems, soil conservation structures, access roads and drainage. For example, a well-designed irrigation system layout may be able to incorporate water harvesting to reuse runoff from paddocks. The layout must also be consistent with any relevant approved water resource plan that may regulate the capture of overland runoff.

Excessive irrigation wastes water, may cause watertable levels to rise, and may leach valuable plant nutrients. To avoid these problems, monitoring soil moisture levels in the root zone can be undertaken with instruments such as tensiometers, capacitance probes (e.g. Enviroscan), or gypsum blocks, and irrigation water only applied when required. Depending on crop type it is generally recommended that irrigation water be applied when field capacity is about 75–80% (i.e. when 20–25% of available water has been used).

Tensiometers are devices that measure soil water ‘tension’ between field capacity and wilting point. The FullStop© wetting front detector (see ‹fullstop.com.au›) can help assess moisture levels in the root zone under irrigation. FullStop© units have no wires or batteries and are buried in the root zone and pop up an indicator that shows when infiltrating water goes past the device. FullStop© also collects a water sample from each wetting front so that fertiliser and salt movement can be tracked.

Fertiliser losses can be high if the full fertiliser requirement for a crop is applied in one application and is then followed by a significant rainfall event. As well as the economic losses there are also the risks of adverse environmental impacts, such as pollution of waterways. A ‘fertigation’ system that applies plant nutrients and irrigation water at the same time can reduce the risk of waste by ensuring that the correct balance of nutrients and water needed by the crop is maintained throughout its growth.

Drainage

Good drainage is critical for horticultural crop production. Subsurface drainage is important for plant growth and surface drainage is important for erosion control. Many horticultural crops are vulnerable to root diseases that thrive in waterlogged soils. Some crops are highly sensitive to waterlogging and may not survive waterlogged conditions for more than a few hours. Low areas where water accumulates can become boggy, interfering with access and with cultivation.

The drainage characteristics of a soil are most evident during extended wet periods. A young crop may survive in a poorly drained soil that is wet for only a brief time. However, a mature crop could suffer severely under the same conditions because the roots of mature plants are extracting water from lower in the soil profile, where the drainage problem is most severe and the soil most likely to remain waterlogged for a long period. To be suitable for horticultural use, a soil must be well drained at least to the rooting depth of the crop.

Drainage can be improved by land levelling, by installing drains, and/or by growing crops on hilled furrows, raised beds or mounds. Before commencing works such as this, accurate detailed information on soil types and surface levels should be obtained. Land slopes and levels can be deceptive, so it is recommended that laser surveying equipment be used where large areas are to be modified by levelling, bedding or mounding.

As nutrients and organic matter are concentrated in the topsoil, crops may struggle to grow on the exposed subsoil in scalped areas where topsoil has not been replaced. Poor soil structure, poor sodicity or salinity, or internal drainage problems are more likely. Where the land slopes are steep and significant cuts are required, topsoil should be set aside and stored for replacement over disturbed areas.

Improvements to assist soil drainage may lead to problems with soil erosion, especially on steep slopes. This is because such improvements are specifically designed to rapidly remove surface water. It can be challenging to provide adequate drainage while at the same time ensuring that the removal of excess water does not cause erosion. Various options for surface and subsurface drainage are discussed in detail in later sections of this chapter.

Crop protection

Damage by animals, birds and hail can lead to significant losses of horticultural crop production. Particularly for tree crops in southern Queensland, construction of large netted enclosures has become the preferred option to protect crops from such damage. These measures also have the added benefit of modifying the microclimate in orchards, leading to improved water use efficiencies. When installing such structures, guy wires and strainers to support net fabrics need to be located with consideration to access, irrigation layouts and maintenance of soil conservation works.

Land surface modification

The land surface for horticultural crops is often substantially modified to manage drainage and to increase effective soil depth. Such modifications may be made on a temporary basis for short term crops, or permanently in the case of tree crops. The most common land surface modification systems are raised beds, mounds and terraces. These are described in detail in Section 12.4.

12.3 Maximising ground cover

The benefits of using ground cover are that it:

- protects soil from erosion by reducing the impact of heavy raindrops
- reduces the volume and speed of runoff
- conserves soil moisture
- protects the crop from weed competition
- helps break disease cycles
- creates microclimatic conditions in and near the soil surface which can enhance soil health and fertility.

Caution is required, however, concerning the choice to match with ground cover to particular crops. For example, some ground covers alter the microclimate to favour pests such as fungi that may be detrimental to some horticultural crops.

Permanent sod cover—such as native or introduced grasses or legumes—is commonly used between tree crop rows. Sod can be periodically slashed or controlled with herbicides or desiccants to provide a mulch cover in the under-tree shaded areas.

Small crops are most vulnerable to erosion in the seedling stage when their above-ground parts are fragile and when their roots are easily exposed and damaged by raindrop impact or runoff. Catastrophic losses due to intense storms at this stage can be reduced by not planting during or just prior to high-risk periods, or by staggering plantings across the property and so reducing the proportion of the crop susceptible at any one time. However, maintaining good ground cover between and during crop rotations is always the best way to prevent erosion.

Ground cover can be provided by inorganic materials such as sheets of plastic, or by organic matter such as a cover crop or mulch. In some instances, it can be provided by the soil itself. For example, gravelly soils used for long-term crops such as pineapples can become more resistant to erosion when raindrop splash has removed topsoil, leaving a high proportion of gravel which has the effect of 'armouring' the soil surface.

Cover crops are widely used to provide protection during the fallow period between the harvesting of one horticultural crop and the planting of the next. They can also provide in-crop protection, for example, under tree crops and in the drains between beds and mounds. A 'green manure' crop is where a cover crop is ploughed back into the soil to improve organic matter levels. Alternatively, a cover crop can be sprayed with a herbicide and the resulting stubble left on the surface to provide erosion protection.

A diverse range of cover crops are used in Queensland (Table 12.1), and local advice should be sought to determine the best cover crops for specific situations. Selecting the correct cover crop depends on the particular circumstances, including the soil type and climatic region, the production system and the season in which the fallow period occurs. Apart from providing erosion protection, the right choice of cover crop can also improve soil fertility by increasing organic matter and nitrogen, and by maintaining soil biological activity. Cover crops such as hay are also suitable for use as animal forage.

Cover crops are sometimes sown in a mixture, such as a cereal and a legume, to provide the benefits of both, protecting the soil surface and rebuilding soil nitrogen for the following crop.

Cover crops can help prevent weeds or pests in planned horticulture crops; fallow crops in bananas, for example, have been shown to help control damaging nematodes (Akehurst et al. 2008; Djigal et al. 2012), and a well-managed fallow or cover crop can minimise weed issues in future crops. It is important to select a cover crop that will not encourage pests or diseases that will impact on adjacent or future crops.

Table 12.1: Cover crops used in Queensland horticulture

Summer growing:		Winter growing:	
Cereal crops	**Legumes**	**Cereal crops**	**Legumes**
• forage sorghum • millet • maize	• cow pea • Dolichos bean • pigeon pea (best incorporated with cereal crops) • soy bean • mung bean • lucerne (3–5 year rotations)	• oats (widely used in south- east Queensland) • wheat • barley • triticale • annual rye grass • millet (South-east Queensland, late winter)	• lupin • field pea • chick pea

Non-living organic matter such as cane trash, mill mud, hay, woodchip or bagasse is also often used to provide ground cover between and during crop cycles. Organic amendments such as these increase soil organic matter levels as they decompose and become incorporated into the soil. The coarser materials will break down more slowly and provide cover for longer periods. The use of non-living cover avoids competition with the production crop, and has the added benefit of not needing to be sprayed out or cultivated, as would be required by a living cover crop.

It may be necessary to add extra nitrogen in the form of an inorganic fertiliser to balance the carbon/nitrogen ratio, unless the amendment contains a significant amount of nitrogen as does, for instance, compost. Adding the extra N to carbon-rich materials gives soil organisms a source of N that they need to decompose carbon-rich organic materials, rather than depleting N from the soil store.

Depending on season, temperature and soil moisture content, organic matter should be incorporated into the soil 4–8 weeks before planting vegetable crops to allow it to breakdown, otherwise serious losses may occur from damping-off diseases. The sudden release of nitrogen from decomposed organic matter can cause growth flushes in crops like tomatoes, resulting in the shedding of flowers as the plant stays in a vegetative stage instead of a fruiting stage. This is less of a problem after first fruit set.

12.3.1 Maintaining ground cover where the land surface is not modified

If a pasture already exists and the land surface is to remain undisturbed, trees or vines can be planted into a narrow cultivated strip. Alternatively, specific planting locations can be spot-sprayed with herbicide to maintain maximum ground cover. Where this method has been applied, pasture growth in the inter-row area can be controlled by periodic slashing, and the clippings spread under the crop trees or vines to provide mulch cover along the rows.

Where there is no pre-existing pasture, an annual cover crop such as millet or oats may be established prior to planting the trees or vines and then permanent grass cover subsequently established by sowing into the cover crop. The term ‘sod culture’ is sometimes used to refer to this type of permanent grass or grass/legume cover in an orchard. Irrigation may be required for sod culture to be feasible in areas of low rainfall where the grass and legumes may compete with the crop for moisture and nutrients. However, the amount of supplementary water required will be reduced, in part by the greater infiltration encouraged by the sod. Regular mowing with clippings left to decay in situ will increase organic matter and recycle nutrients.

Where crops are annual or seasonal, it is necessary to prepare a seedbed in which to establish new plants each successive year or season. Intensive cultivation to prepare a fine seedbed should be avoided as it reduces soil organic matter levels, damages soil structure and destroys ground cover. Bare fallows are especially vulnerable to erosion if they occur during the summer months in Queensland, when rainfall is most intense. Horticulturalists are increasingly adopting reduced- or no-tillage practices to minimise such problems. A reduced-tillage practice is one for which the number of cultivations to prepare a seedbed are kept to a minimum and the crop is planted into stubble that has been only roughly incorporated into the soil.

A no- or zero-tillage system is one for which the soil is not cultivated, and instead modified planting machinery with coulters that cut through trash is used to plant a crop directly into stubble. Insufficient timelag before planting may result in heavy losses from damping-off diseases that can occur when organic matter in the soil breaks down around young plants or sown seed.

12.3.2 Maintaining ground cover where the land surface is formed into beds

Beds are usually formed just before planting the annual crop and are then covered with plastic sheeting. However, if they are formed some time before the crop is to be planted, both the beds and the drains between the beds can be planted with a cover crop to protect against erosion. If necessary, this cover crop can later be removed—by spraying out with herbicide, by cultivation or slashing—before sowing or planting the horticultural crop.

Pineapples are commonly planted into beds (Figure 12.3). At the completion of a pineapple harvest, large amounts of trash (200–300 tonnes/ha) may be left on the soil surface. Retaining this trash on the ground will reduce soil erosion, improve soil health and increase crop yields. The trash provides food for soil organisms and plant nutrients and may reduce the amount of fertiliser required by the next crop rotation.

On areas that are steeper than 3%, or in areas historically prone to erosion, pineapple growers are increasingly using inter-row cover crops. Where cover crops are not used in the drains between beds, mulch from a previous pineapple crop can be spread in these areas to provide cover over the lower sections. Pineapple plants can also be established, in ‘clusters’ at regular intervals (5 m) across a drain or walkway, to slow the water running down the drains and to trap soil.

Figure 12.3: Using oats as a green mulch in the inter-bed to reduce soil loss

Crops grown in beds with drip (or trickle) irrigation systems—tomatoes, melons, capsicums, zucchini, strawberries, for example—often use polyethylene plastic mulch as ground cover. The plastic mulch helps to reduce the requirement for water and fertiliser, suppress weeds, reduce disease, increase yields and improve fruit quality. The plastic will also protect the soil in the bed from erosion caused by raindrop impact. The mulch is laid out over the formed beds and seedlings or seeds are planted directly through holes made in the plastic.

However, the plastic sheeting will concentrate runoff to the drains between the beds and this increased runoff may lead to scouring. It may also, potentially, persist in the environment long after its use. Biodegradable polyethylene mulches have been trialled to overcome these problems. The best biodegradable mulches (often starch based) have a known use-life and are broken down by soil bacteria and by exposure to sunlight as the crop matures. This technology has been used commercially in tomato crops in the Bowen district in recent years.

12.3.3 Maintaining ground cover where the land surface is mounded

Perennial crops such as pome fruits (apple, pear or related fruits), citrus, bananas, avocado and macadamias are often planted on mounds separated by drains. In these circumstances, erosion protection can be rapidly provided by sowing a cover crop over the whole area soon after the mounds have been constructed. The cover crop can later be spot-sprayed out with herbicide in the locations where the crop trees are to be planted to avoid adverse competition.

Depending on the land slope, ground cover may be required permanently in the drains between the mounds to prevent erosion. In these areas, cover can be sown or provided by volunteer vegetation species encouraged and managed by slashing. As the tree crops grow and their canopy expands and becomes denser, the amount of light reaching the ground in the inter-row areas will decline and hence the growth of ground cover species will diminish. While this will have the positive effect of reduced competition for the crop, it will also reduce the effectiveness of the ground cover in protecting the soil from erosion. The tree canopy provides some protection from direct raindrop impact; however, drips from tree branches can have a similar effect as raindrops. The extent to which rain is collected and dripped from branches and foliage will vary with the architecture of the tree crown. Some species such as macadamia capture and funnel rainfall down their trunks, directing it to bare soil at the base; others shed water from outer parts of the crown. Vehicular and foot traffic in the inter-row areas required for harvesting, disease and weed control may also slow growth of groundcover species.

A partial solution is to use groundcover species that tolerate low-light conditions (Table 12.2). Another option concerns the increased mulch that will occur over time from the shedding of leaves as part of the normal growth of the trees. Where trees are pruned, or where inter-row areas are mowed, the pruned material (provided it is disease-free) or the grass clippings can be placed under the trees to act as mulch. Other organic materials such as cane trash or compost sourced from other areas may also be useful. Judicious pruning may also help to increase the amount of sunlight reaching the inter-row areas, as will increasing the spacing between trees. In old established orchards where trees are narrowly spaced, individual trees can be selectively removed or renovated to increase the amount of light reaching the ground.

Table 12.2: Groundcover species that tolerate low light levels

Common name	Scientific name
Broadleaf carpet grass	*Axonopis affinis*
Sour grass	*Paspalum conjugatum*
Sweet smother grass	*Dactyloctenium australe*
Creeping vigna	*Vigna parkeri*
Lotononis	*Lotononis bainesii*
Buffalo grass	*Stenotaphrum secundatum*
Blue couch	*Digitaria didactyla*

For bananas, Akehurst et al. (2008) recommended the following for managing ground cover:

- Establish cover crop across the whole area prior to planting.
- Spray out a 1 m wide circle at the planting site for each banana plant then wait until the herbicide is neutralised over several weeks before planting.
- For cover crops in young banana plantations, spot-spray around plants with an appropriate herbicide as required. Weed control should not be needed in inter-row areas for at least six months if the cover crop is well established.
- Increase the width of the sprayed spots or strips progressively in the crop plant rows. By about 12 months there should be about 1 m of cover crop left along the middle between each row.
- Allow residual inter-row strips of cover crop to set seed and self-sow to re-establish the cover in the previously sprayed area.
- Recommence the spraying cycle after the following autumn.

12.4 Managing runoff

Runoff that erodes cultivated paddocks removes precious fertile topsoil, thus exposing less productive subsoil. Runoff from intensive farming enterprises like horticulture can contain large amounts of nutrients. and possibly some sediments and plant pathogens, which can enter water bodies downstream.

Runoff control structures should be designed to ensure they have adequate capacity to carry estimated runoff at rates that will not erode the channel of the structure. The size and gradient of such structures will depend on:

- the size and land use of the contributing catchment
- soil type
- land slope
- surface condition of the channel structure, either bare or degree of vegetal cover.

Works and measures used to manage runoff and drainage water in horticultural lands include earthen or vegetation barriers that increase infiltration thereby reducing the volume of runoff; or they may collect runoff, reduce its velocity, and/or divert it to stable disposal areas. Options include:

- diversion banks
- levee banks
- sediment traps
- waterways or drains
- raised beds
- mounds
- bench terraces
- contour banks or contour drains
- vegetated strips.

Some of these options involve structures that run across the slope while others run up and down the slope. Structures across the slope discharge runoff into a stabilised down-slope waterway or drain. Those aligned up and down may discharge runoff into cross-slope interception structures or directly onto a grassed headland or watercourse.

The following sections provide broad guidelines on the application of these works to manage runoff in horticultural enterprises. More detailed information on how to design structures to achieve this is provided in other chapters of these guidelines—Chapter 3 Estimating runoff; Chapter 6 Hydraulic design principles; Chapter 7 Contour banks; Chapter 8 Diversion banks; and Chapter 9 Waterways.

Blockages may occur when layouts are not properly planned, or are poorly constructed, creating low points that accumulate runoff until overtopping occurs. Other causes of blockages include:

- sediment deposition
- dense grass growth
- raised roads
- soil windrows created by road grading
- traffic driving over outlets
- channels with insufficient capacity
- waterways that are too shallow to accept runoff from furrows.

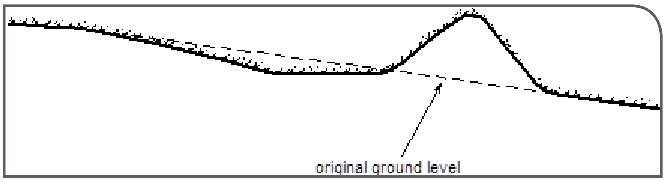
The outlet ends of waterways, furrows, walkways, terraces and mounds must drain freely and should not be blocked by raised roads, windrows from recent road grading or silt accumulations. It is important that any of these be addressed as soon as evidence of blockages occurs, to minimise risks of serious erosion from a future rainfall event.

12.4.1 Managing runoff with diversion banks

Diversion banks (Figure 12.4) collect runoff from areas upslope from a crop or plantation area and divert it into a safe disposal area. Diversion banks normally have a grassed channel and will usually direct runoff to a vegetated waterway, or a stable disposal area.

If the channel is well grassed, gradients of up to 5% or more can be used, especially for relatively short diversion banks on steep slopes that are typical of horticultural applications. A diversion bank with a steep gradient may also be referred to as a one-sided waterway. If the channel is bare, or poorly grassed, the diversion bank gradient should not exceed 0.5%.

Figure 12.4: Cross-sectional view of a diversion bank



As with all interception structures, the capacity—or cross-sectional area—of a constructed diversion bank becomes less as the gradient of the land slope increases. That is, the capacity of a diversion bank of a given height will be less on a steeper site than one of the same height on flatter land. It may be impractical to build diversion banks on slopes steeper than about 15%. For more information on diversion banks see Chapter 8.

12.4.2 Managing runoff with levee banks

Many streams on floodplains have natural levees that are created by the deposition of coarse sediments where floodwaters first escape from the stream channel. For this reason, the stream bank may be the highest land on some floodplains. Artificial levees may be constructed on floodplains, providing flood protection to adjacent land and to other assets such as buildings. Levee banks built parallel to a watercourse act to contain the floodwaters within the watercourse; those built across the floodplain act to divert the floodwaters to adjacent areas. Levee banks may also be part of an irrigation scheme to harvest water.

Floods naturally spread out across the floodplain, and any structure or measure that interferes with this spread may increase the velocity of flows or divert them in new directions, potentially flooding other areas. Also, if a levee bank fails, the area it was designed to protect may suffer severe damage.

When planning an artificial levee bank, any legislative requirements should be considered, particularly the Water Act 2000 that regulates the construction of levee banks. See Chapter 10, Land management on floodplains for more information on levee banks.

12.4.3 Managing runoff with waterways (or drains)

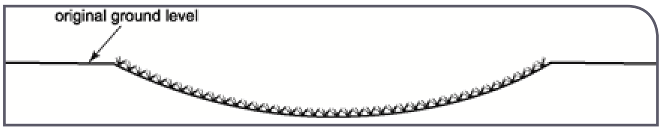
Artificial vegetated waterways are designed to transport runoff down and across the slope so it can be safely discharged into a stable area without causing erosion. Other runoff interception structures—diversion drains, contour banks, across-slope beds and mounds—are usually built to discharge to such waterways (Figure 12.5). In the horticulture industry these are often just referred to as 'drains'. They may be 'subsurface', and depending on channel gradient they may be bare (i.e. not vegetated).

When planning the location of waterways, consideration should also be given to the likely course runoff would follow naturally, and the damage that would potentially result if a waterway was to fail or overtop in a rainfall event that exceeds the design parameters. Waterways should be designed so they have sufficient capacity to contain the runoff they would be expected to carry for a nominated design period—for example, once in 10 years–or greater if a higher level of protection is needed. Information on design of waterways is provided in Chapter 9.

Figure 12.5: A grassed waterway with banks to contain runoff

For horticultural enterprises, waterways (or 'drains') are often constructed below the surface level to ensure crop rows or inter-row drains can discharge directly into the channel (Figure 12.6). The waterway should be deep enough to accept runoff from adjacent inter-row drains. In order to accommodate the furrow or drain depth, such waterways will often have much greater capacity than that determined by a waterway design.

Figure 12.6: Subsurface waterway with a parabolic shaped channel



Subsurface waterways may be constructed with a flat bottom or preferably with a parabolic-shaped channel. A waterway should be stabilised before adjacent rows, drains or banks are installed to discharge runoff flows into them. They can be stabilised with grass species such as carpet grass or couch to ensure runoff will be conducted safely down the slope without causing erosion. Appendix 4 of these Guidelines lists plant species that are suitable for stabilising soil conservation projects in Queensland.

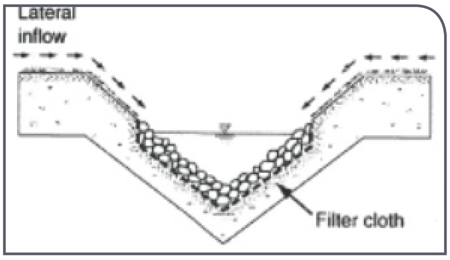
Where possible, herbicides should not be allowed to enter a vegetated waterway. Also, shade trees and plantation trees should not be planted too close to stabilised waterways or ephemeral streams if there is a risk that shade could inhibit protective cover in the waterway channels and increase the risk of erosion. Constructed waterways should not be used for vehicular traffic as frequent traffic can also destroy cover leading to erosion.

While grass or other pasture species are most commonly used to stabilise a waterway, other (higher-cost) alternatives are shown below. A number of these commercially available products can improve the durability of waterways, and allow for much greater flow velocities to be carried.

The suppliers of these products can provide advice on comparative costs and design requirements.

- **Reinforced turf:** specially designed with a UV-stabilised mesh reinforcement to withstand much higher runoff velocities than normal turf
- **Turf reinforcement mats:** various products woven into a three-dimensional web to provide good initial ground coverage but allowing the growth of vegetation through the mat. Trapped sediment provides additional stability to the system
- **Rock:** set in cement or contained by wire netting with a geofabric underlay (Figure 12.7)
- **Concrete-lined drains:** as used in the pineapple industry (see below)
- **Geocells or cellular confinement systems:** honeycomb-shaped cells made of polyethylene filled with topsoil and turfed or filled with gravel and covered with a close-weave wire netting
- **Butyl rubber or UV-resistant PVC sheets:** provide immediate protection to relatively small areas with minimal need for preparation of the surface to be covered
- **Spray-on chemicals:** to stabilise the surface soil.

Figure 12.7: Rock-lined waterway (Catchments and Creeks, 2010)



It was previously common practice among pineapple growers to construct temporary waterways to collect runoff from the furrows between rows of pineapples. These U-shaped structures were built by pouring a weak slurry of concrete from the top of the waterway. The sides of the channel were then shaped with a yard broom as the concrete slurry ran down the drain. At the end of the crop cycle, these temporary waterways were ploughed out. This system is rarely used now, as many farmers have moved from a 4–5 year ratoon crop to a fresh fruit crop cycle of 18–20 months.

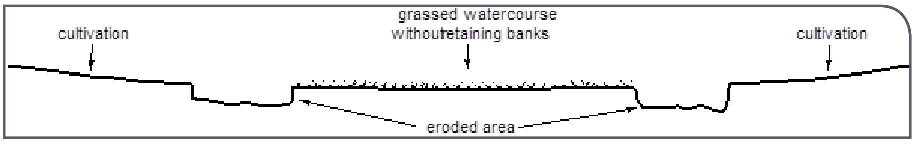
On steep slopes, concrete-lined drains were installed to intercept and divert runoff moving down a hill slope. Under very wet conditions these drains have been known to fail as the sides of the drain eroded, undermining the concrete walls and initiating major rill or gully erosion. Lining the channel with a suitable geofabric filter fabric prior to applying the concrete, and including drainage 'weep holes', may help to alleviate the risk of failure.

There is also a risk that waterways subject to flows for extended periods will become boggy and vulnerable to failure. In these situations, subsurface drainage will provide more protection.

Natural waterways that are well vegetated and level with the ground surface may have limited capacity to constrain runoff and therefore could be at high risk of serious erosion either side of the channel (Figure 12.8). As runoff will follow the least line of resistance it will not flow through the vegetation unless confined by banks constructed parallel to the waterway or in a subsurface waterway. To prevent erosion adjacent to a natural waterway, banks should be installed to constrain the flow within the watercourse.

An alternative is to excavate a subsurface channel, necessitating re establishing the protective vegetal cover.

Figure 12.8: Erosion in a natural watercourse with limited capacity to accommodate runoff

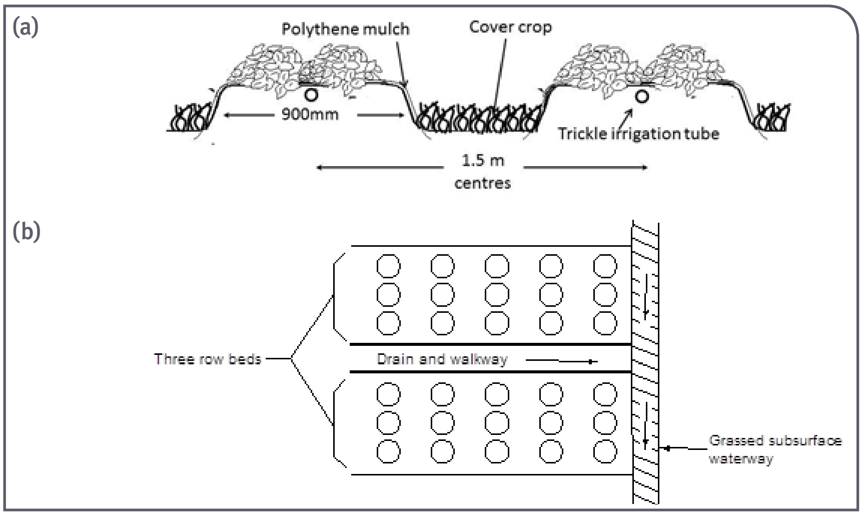


See Chapter 9 for detailed information about soil conservation waterways.

12.4.4 Managing runoff with raised beds

Raised beds are most commonly used with annual or seasonal crops such as vegetables. Most raised-bed systems are reinstated after each crop cycle, although some farmers use 'permanent' beds through a number of crop cycles. Figure 12.9a is an example of double-row beds for strawberries with trickle irrigation and plastic sheeting. Figure 12.9b is a plan view of a crop with three rows in the bed.

Figure 12.9: Raised bed systems: a) two-row system of strawberries in section; b) three-row system in plan view (note: in practice, bed widths depend on wheel track width of machinery used)



Benefits from raised-bed systems include:

- increased depth of soil for plant growth
- improved drainage
- reduced soil compaction by restricting traffic to defined pathways
- improved access for crop management and hand-harvesting
- improved control of in-field runoff.

The specialised machinery used to form beds can have attachments that lay plastic sheeting as well as trickle tubes for irrigation. Plastic sheeting provides weed control, keeps the crop clean and minimises fruit rot, but it also increases the amount and rate of runoff from a block, thereby increasing the erosion risk in the inter-bed furrows or drains and in downstream structures.

Local catchments, ridge lines, land slopes and drainage layouts should be taken into account when planning a raised-bed system. Raised beds are separated by furrows or drains that can also be used as transport corridors for foot traffic or machinery and, as a result, can become compacted. This can have both benefits and disadvantages.

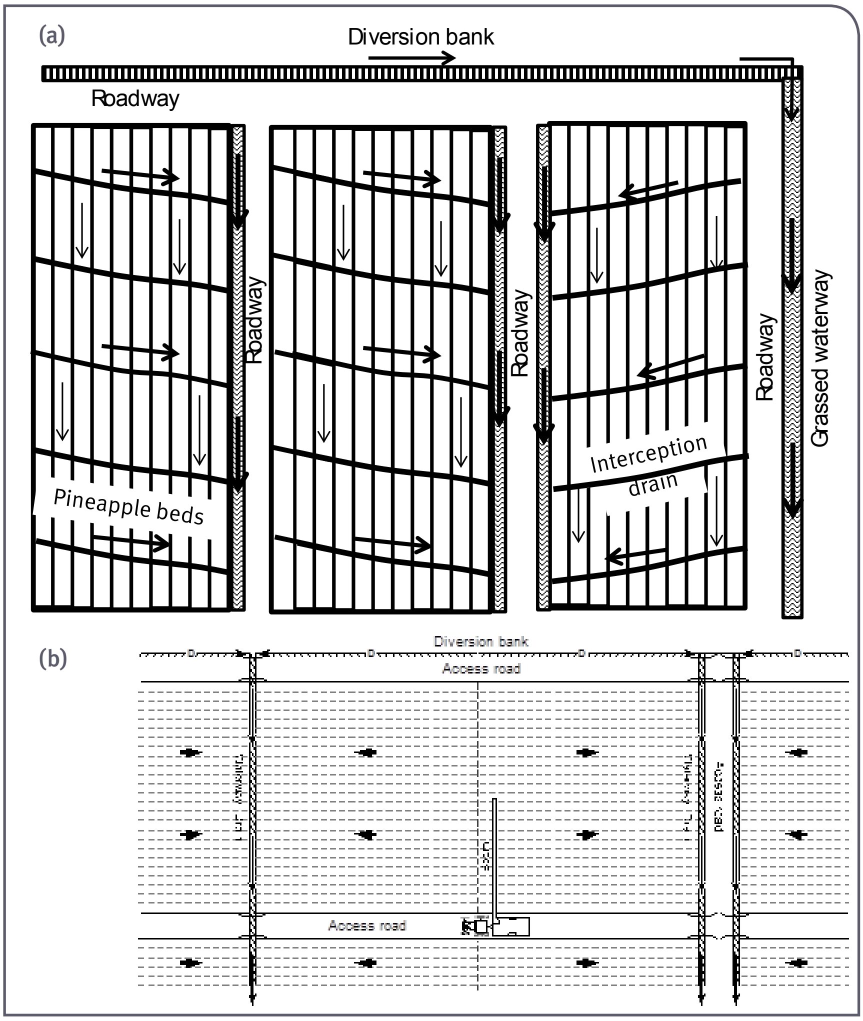
On the one hand, a compacted furrow or drain will tolerate higher velocities than a loosely tilled surface will, and it is therefore more resistant to erosion. On the other hand, a compacted soil will also have a reduced infiltration rate, resulting in an increased volume of runoff and therefore requiring downstream structures to have greater capacity. A compacted surface will also provide less resistance to flowing water than a loose surface will, and this leads to higher water velocity and increased erosive power of the runoff.

The velocity of flow in an inter-bed furrow or drain depends on its width, length and surface condition: the wider the drain, the greater its capacity, resulting in a lower potential for erosion. Therefore a flat-based—trapezoidal, parabolic or U-shaped—channel between the beds is preferred to one with a V-shape. Flat bases also make better walkways and have lower runoff velocities, meaning better erosion control. Importantly, after a series of rainfall/runoff events, the shape of a drain profile can change over time. This has been especially so in crops such as pineapples where the crop cycle was 3–5 years, although it is now less of a problem with the advent of shorter crop cycles.

Inter-bed furrows or drains should have enough gradient to ensure effective drainage occurs but not enough to allow excessive velocities that cause erosion. The most suitable gradient will be influenced by how the beds are aligned in relation to the landscape: being either aligned close to the contour of the land (Figure 12.10a); diagonally across the slope; or up and down the slope (Figure 12.10b). Where the prevailing slope of the land is greater than 5%, it is difficult to traverse the slope, so beds aligned up and down the slope are more practical.

Longer beds or furrows mean greater volumes of runoff, and hence the depth of flow and potential rates of erosion are higher. Where erosion risks are high, the contributing catchment to each furrow can be reduced by installing contour banks, or interceptor cross-drains, after the crop has been planted (Figure 12.10b). Row/bed length also affects the efficiency of farming operations. Long rows may increase the efficiency of machinery use but if a crop is hand-harvested with buckets, row length should be taken into account so that buckets do not have to be carried a large distance when full.

Figure 12.10: Plan view of layout in a pineapple plantation: a) gently sloping land with beds aligned across the slope; b) steeper land with beds aligned with the slope



Bed design

There is no readily available, simple method to determine the precise specifications for a bed system in a particular situation. The following sections provide some guidance but this should be combined with local experience.

The capacity of an inter-bed furrow to accommodate runoff and its flow velocity can be affected by a number of factors such as the following:

- gradient of the furrow/drain
- height of bed—depth of flow
- surface condition—soil tilth, or bare and compacted; presence of vegetation or mulch
- shape of furrow channel
- contributing catchment—length and width of beds, and land slope
- soil type.

Important note: Raised beds with furrows or drains that are bare and with gradients of less than 1% will not be at risk of erosion for most soils used for horticulture. Raised-bed systems with furrow gradients steeper than 1% will require some form of channel protection, such as grass or mulch.

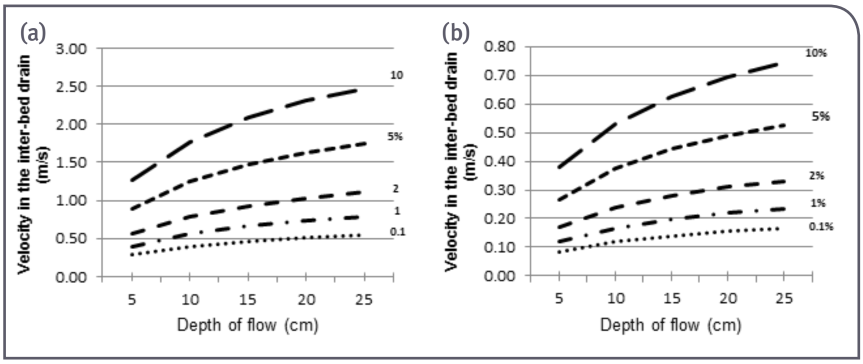
If more detailed design is required, the channel design principles of Chapter 6 should be reviewed. In summary, Chapter 6 outlines how a channel's shape, roughness, gradient and depth of flow can affect the flow velocity. The Manning formula is used to assess these characteristics and attributes values to a range of surface roughness conditions, known as Manning's n roughness values.

For a smoothly tilled, bare soil that is common for furrows or drains in a horticulture raised-bed system, the Manning's n roughness value will be around 0.03. On such channels, velocities can become erosive once they exceed 0.3 m/s for self-mulching black soil, or 0.5 m/sec for erosion-resistant soils such as ferrosols.

However, if the surface is covered with a dense crop or grass sward, the Manning's n roughness value can be 0.10 or greater and the flow velocity greatly reduced. A channel with good cover can tolerate velocities of 1.0 m/sec or greater without eroding. The acceptable or permissible velocity will depend on the density and type of cover, channel gradient and erodibility of the soil. See Table 9.1 in Chapter 9 for recommended maximum velocities for a range of surface conditions, channel gradients and soil types.

Figure 12.11 illustrates the different velocities that can be expected when comparing channels with a bare soil condition (i.e. Manning's n of 0.03) with those that have a good vegetation cover (Manning's n of 0.10), and for a range of channel gradients and depths of flow. For example, Figure 12.11a shows that for a bare soil condition in a channel with a 1% gradient, a safe flow velocity of about 0.5 m/s occurs at depths below 10 cm. As seen in Figure 12.11b, however, a channel with good vegetation cover (Manning's n of 0.10) can have a flow velocity of 0.75 m/s on a 10% gradient at 25 cm depth.

Figure 12.11: For a bed width of 40 cm and variable gradient, flow velocities in furrows between raised beds for Manning's n of: a) 0.03; and b) 0.10



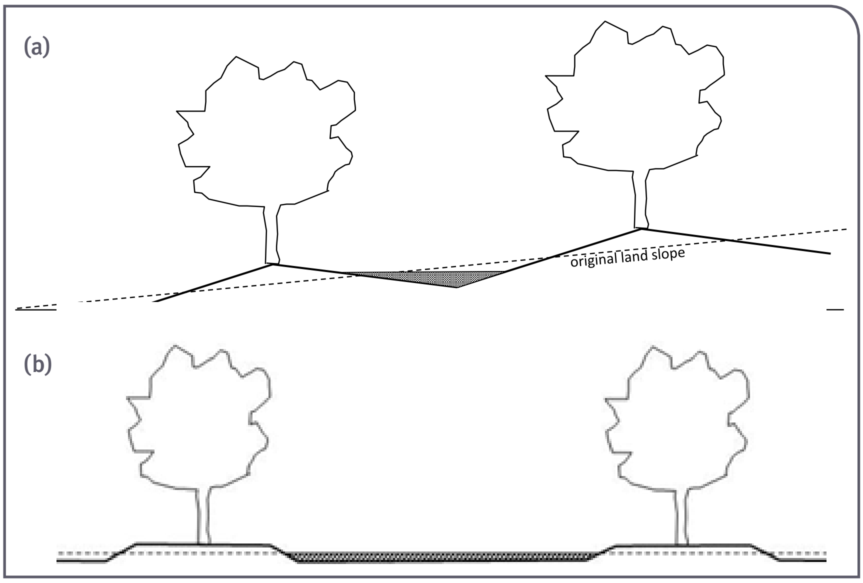
As noted earlier, the gradient that is acceptable also depends on the condition of the bed of the drain. If the soil in a furrow or drain is bare (Manning's n of 0.03), the bed is likely to erode for gradients exceeding 0.5%. If the furrow channel is vegetated (Manning's n of 0.1), gradients of 5% can be acceptable. If the inter-bed furrows are lined with plastic higher gradients can be tolerated but higher rates of runoff can be expected.

12.4.5 Managing runoff with mounds

The use of mounds for horticulture requires some relatively costly earthworks. Most other soil conservation measures used with permanent and semi-permanent crops can be easily modified at relatively low costs if mistakes are made and erosion occurs—not so with mounds. For this reason, Section 12.4.5 provides more extensive detail than is given in the sections on other runoff control structures.

Mounds are used with tree row crops such as papaws, macadamia nuts, avocados, citrus, vine crops and bananas. They maybe cross-slope or up-and-down slope. Figure 12.12 shows typical cross-sectional views of mounds.

Figure 12.12: Typical mound cross-section with channel a) cross-slope and b) up-and-down slope



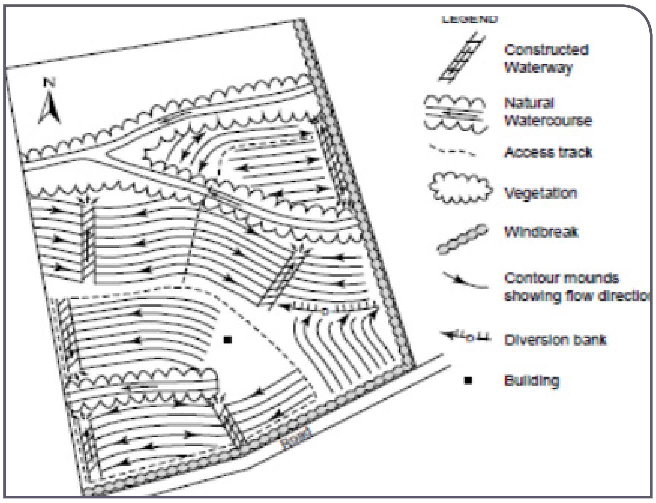
Mounds provide the following advantages:

- A good depth of a well-drained soil boosts productivity and makes crops less susceptible to root diseases.
- The channel between the mounds acts as a drain to provide good surface drainage and to manage runoff for erosion control on sloping land.
- A mound provides improved access to the plantation, especially under wet conditions, and safer access where cross-slope mounds are used on steep slopes.

When planning a mound system, it is important to take account of local catchments, ridge lines and drainage lines so that the drains in a mound layout discharge to an outlet such as a natural drainage line, a subsurface waterway, or an in-field diversion bank.

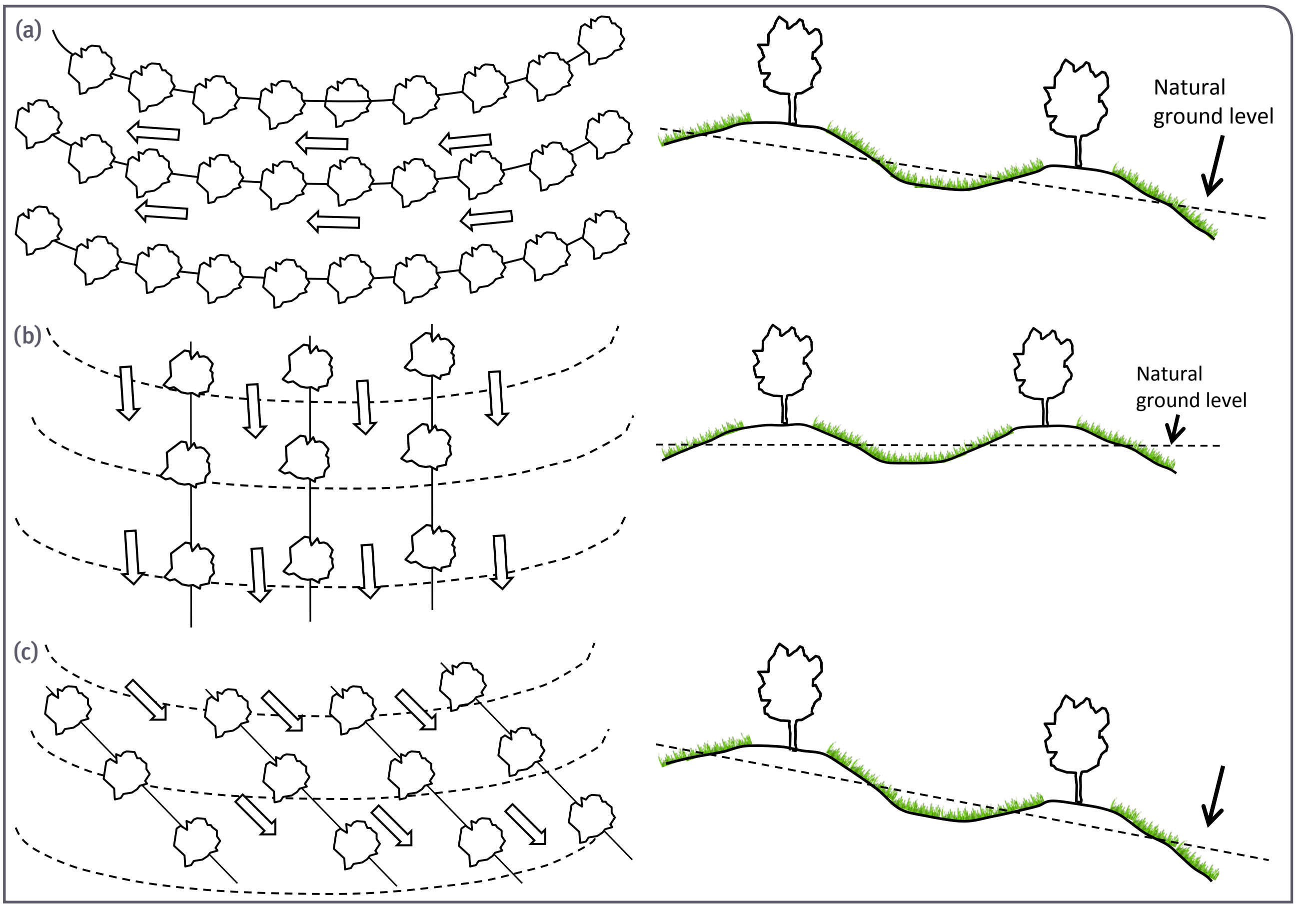
Figure 12.13 is an example of where the layout has taken good advantage of ridge lines and natural drainage lines.

Figure 12.13: Banana plantation layout taking good advantage of natural slope and drainage



Mounds may be aligned close to the contour (Figure 12.14a), directly up and down the slope (Figure 12.14b) or at any angle in relation to the contour (Figure 12.14c).

Figure 12.14: Aerial view and cross-section of mounds a) aligned to the contour, b) directly up and down slope, and c) diagonal to the slope



Each of these options can provide adequate erosion control if grassed channels are used where erosive velocities are likely to occur. Mounds aligned to the contour are comparable to a continuous sequence of contour banks, whereas mounds up-and-down or diagonally across the slope are comparable to a continuous series of grassed waterways. Table 12.3 summarises the major issues related to mound alignment.

Table 12.3: A comparison of different mound directions

Issue	Mounds aligned to the contour or across the slope	Mounds directly up and down hill
Construction	Mounds are difficult to build on steeper slopes, depending on the width and height of the mound relative to the required spacing of the trees	Mounds are easier to build on steeper slopes because less earth is moved
Erosion	Where there are low gradients and vegetated channels, erosion risk will be low. On steep land slopes, the downslope batters of mounds can be very steep and will be prone to erode	For channel gradients >2%, good cover levels are required
Irrigation	Minimal issues for irrigation	Even distribution of irrigation water is difficult due to varied elevations
Crop management and trafficability	Lower gradients in channels improve access, especially on steeper land slopes. On steeper slopes, accessibility to trees from the lower side can be difficult	On steep slopes, walking and driving up the inter-row can affect tree management. Slippage when travelling up steep slopes is likely. Access to trees from the inter-row area is easier than for mounds across the slope

Generally it is more difficult to construct mounds across slopes greater than around 15%. The alternative is to construct mounds up and-down slope where they can be made higher and wider.

Aspect can also be an issue when designing mounds. Mounds situated in a north-south direction maximise sunlight in the rows, which encourages flowering and fruiting. However, where mounds are built on sloping land, factors other than aspect, such as those summarised in Table 12.3, will have a greater influence on the choice of mound direction.

It is essential that measures be taken to prevent runoff from entering a plantation from land external to it, for example, by installing diversion banks or levees to protect the plantation area. If this is done effectively, then the channels or drains between the mounds need only be of sufficient capacity for the runoff that is produced between the rows. This contributing area can be relatively small: for example, for mounds spaced 16 m apart, a 200 m length of mound has a catchment area of just 0.32 ha. Therefore, it is not likely that mounds will overtop, provided external runoff is managed and channels or drains have a continuous gradient to their outlet.

The following are then potential causes for soil erosion in a mound system:

- poor channel cover and steep gradients leading to excessive velocities
- bare soil—or very limited cover—due to shading under the trees, leading to erosion when runoff flows to the sides of the grassed area
- steep land slopes (>20%) where, depending on the height and spacings of the mounds, the downslope batter is greater than 30%.

Key considerations when aligning mounds are:

- management of external runoff
- natural topographic variation (see Figure 12.15)
- selection of stable disposal areas for runoff from the mounds
- crop requirements—soil depth, plant spacing, orientation to sunlight
- channel or row gradients
- location of access tracks.

Mounds aligned on the contour can be parallel with the same or similar gradients, and may be straight or curved. In-field diversions or contour banks may be required to ensure runoff is discharged to waterways.

Figure 12.15: Aerial view of mounds taking account of landscape features

Mounds on the contour in areas prone to frosting can trap cold air, increasing frost damage in susceptible crops. This was seen on the Atherton Tableland (Van Putten 1985), and at Nambour. This is not a concern for mounds aligned up-and-down slope, or diagonal to the slope.

As hydraulic failure is not a major risk with mound systems, any design features then relate to the requirements of the crop. The main design features are the cross-sectional shape (including grade of batters) and gradient of channels, and the height and spacing of mounds.

Cross-sectional shapes of mounds

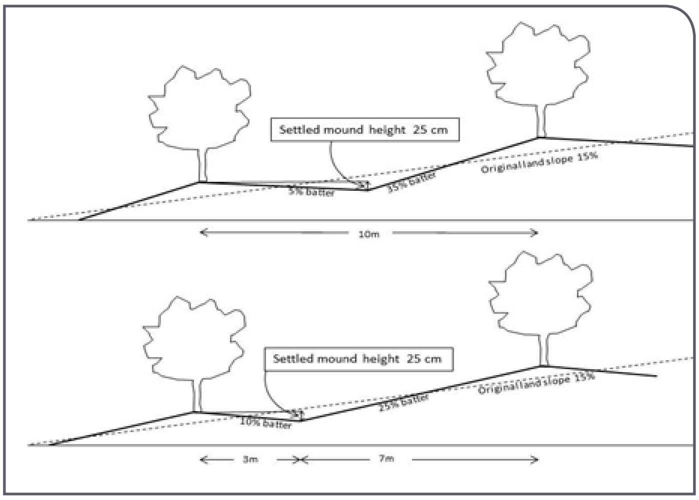
The channels between mounds can have a wide V-shape profile that tends, over time, to develop into a parabolic or saucer shape; or they can have trapezoidal shape with a flat base. The channel shape and width needs to facilitate the use of machinery such as mowers, spray rigs and harvesting equipment.

The maximum slope for the batters is normally about 25%, that is, 1:4 (V:H), although 33% (1:3, V:H) is possible depending on the machinery to be used afterwards. Both batters for mounds up and down-slope can have the same grade irrespective of the original land slope. For cross-slope mounds, the batter on the upper side of the channel will be steeper than the batter on the lower side of the channel (Figure 12.16).

Depending on the height and width of cross-slope mounds, the upslope batter can become very steep, especially on steep land slopes. Generally, batter slopes steeper than about 25% (1:4, V:H) are difficult to traffic and have restricted access to trees from the lower side of the mound. Shade-tolerant species should be planted to minimise erosion on steep batters.

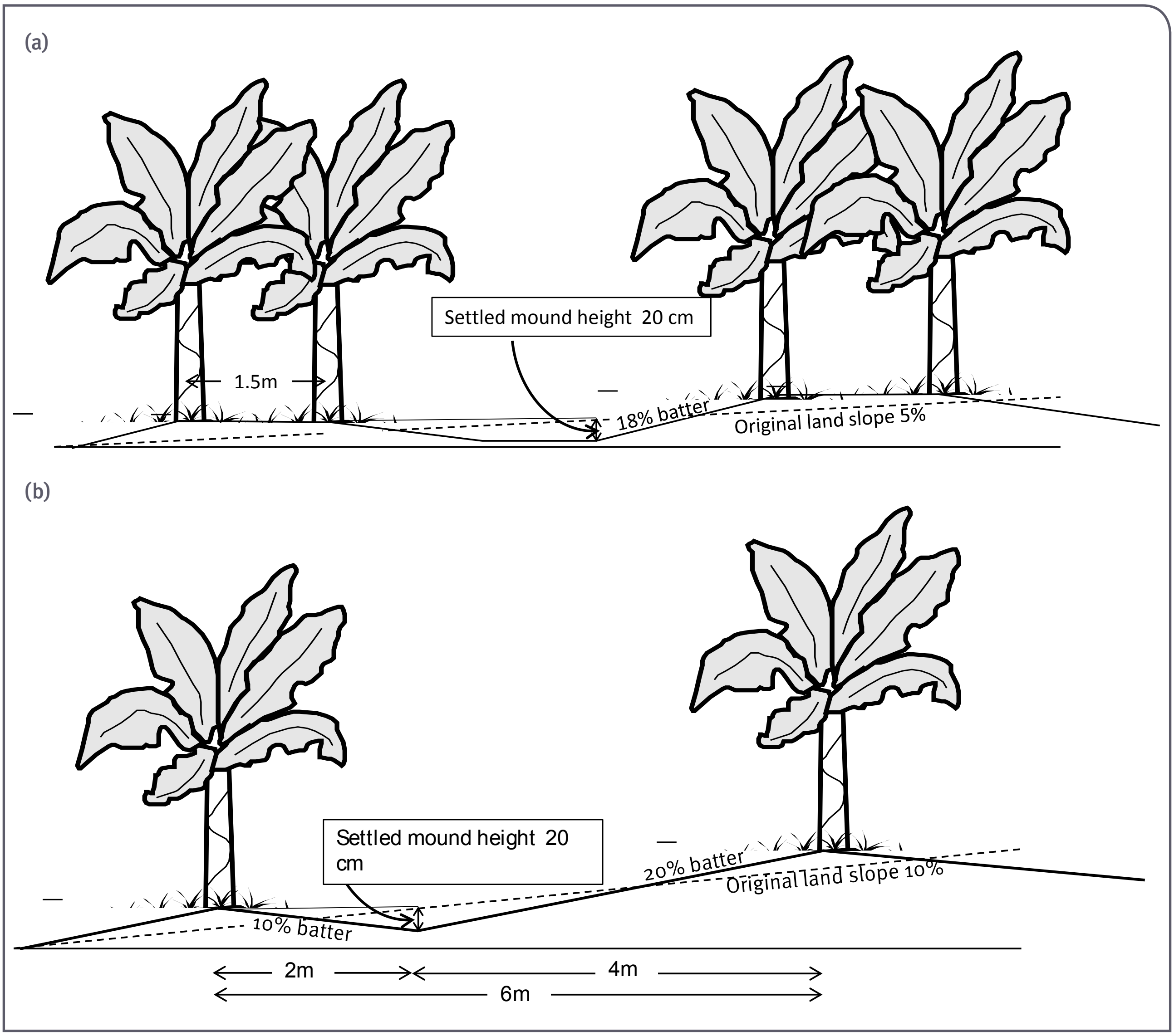
The upslope batter may be made flatter by locating the low point of the channel closer to the downslope mound (Figure 12.17). However, if a 'cherry picker' straddling the channel is to be used for harvesting, it will be a long way to the top of the upslope trees.

Figure 12.16: Slope of uphill batter reduced by offsetting low point of the channel



On banana plantations in North Queensland mounds are often built across the slope to maximise access, especially during wet conditions common in the region. On slopes less than 5%, broad mounds can be constructed with two rows of bananas planted on each mound (Figure 12.17a). On land steeper than 5% it is not practical to build broad mounds across the slope, so mounds are narrower with single rows of bananas on each mound (Figure 12.17b).

Figure 12.17: Typical North Queensland banana plantation layout: a) on land with gentle slope; b) on steeper land



Mound gradient

Channels between mounds require sufficient gradient to discharge runoff without ponding, but not so much as to cause erosion. Where channels are bare, a gradient of at least 0.5% should ensure sufficient drainage without waterlogging. Cross-slope mounds in banana plantations are mostly kept parallel by varying the gradients between a minimum gradient of 1% and a maximum of 3% although for ferrosol soils this can be increased to 4%. For up-and-down slope mounds the gradient is the natural land slope and could be 15% or higher.

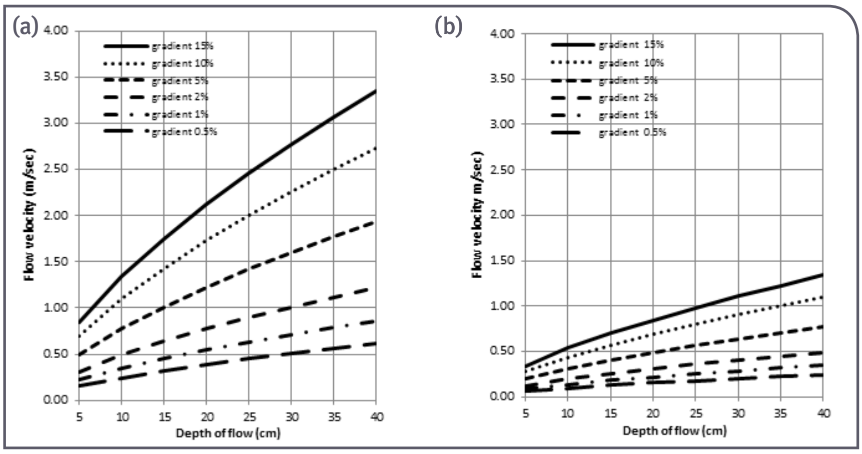
Important note: As with raised-bed systems (see Section 12.4.4), for most soils used for plantation crops, mound channels that are bare will generally have minimum risk of erosion if gradients are less than 1%. For mound layouts with channel gradients steeper than 1%, effective vegetation cover in the channels is essential.

If a more detailed design is required to assess the erosion risks of the inter-mound channels then the channel design principles of Chapter 6 should be reviewed. For a roughly cultivated, bare surface that may be typical of a non-vegetated inter-mound area, a Manning's n value of 0.04 is applicable; while a Manning's n value of 0.10 represents a slashed well-vegetated channel.

A channel with good cover can tolerate velocities of 1.0 m/sec or greater without eroding. The acceptable (or permissible) velocity will depend on the density and type of cover, channel gradient and erodibility of the soil. See Table 9.1 in Chapter 9 for recommended maximum velocities for a range of surface conditions, channel gradients and soil types.

Figure 12.18, using a range of channel gradients and depths of flow, illustrates the different velocities that can be expected when comparing a channel with a bare soil condition with one that has a good vegetation cover. For example, Figure 12.18a shows that for a bare soil condition (Manning's n of 0.04), in a channel with a 0.5% gradient, a safe flow velocity of about 0.5 m/s for a bare soil occurs at depths below 30 cm. In contrast, Figure 12.18b shows that channels with good vegetation cover (Manning's n of 0.10), can have a safe flow velocity of 1.0 m/s on a 10% gradient at 35 cm depth.

Figure 12.18: Flow velocities between mounds for batter slopes of 1:6 and a range of flow depths and gradients with a) Manning's n of 0.04 (roughly cultivated); and b) Manning's n of 0.10 (slashed grass)



For channels with batter slopes of 1:6, Figure 12.18 compares the effect on flow velocity of changing the roughness value from a bare soil condition to a vegetated condition, that is, when Manning's n is increased from 0.4 to 0.1. The following benefits are noted:

- Maintaining a slashed, well-vegetated channel will greatly reduce flow velocities and the slashed material can provide excellent erosion protection.
- Flow depth, even with a long mound, remains shallow (less than 40 cm).
- On flat land (<1%), velocities on a vegetated channel are very low.
- Erosion risk remains acceptable on vegetated up-and-down slope mounds at 15% land slope.

Height of mounds

The main criterion for choosing a mound height is the soil depth necessary for the plantation trees, so the required height will depend on existing soil depth and the requirements specific to the trees. Generally, for most plantation trees a total soil depth of 1 m is considered to be a minimum.

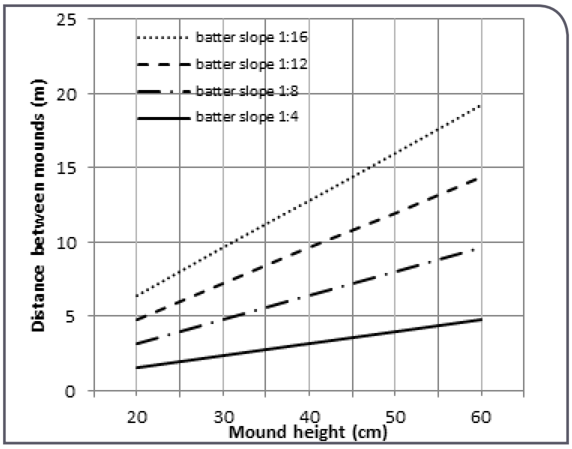
Depth of excavation is another consideration, and this will depend on the soil type and depth of the A horizon. Where infertile subsoils are exposed it will be difficult to establish an effective vegetation cover in the channel.

Mound spacing

The distance between mounds depends on crop requirements. For large trees, such as avocados, mangoes and macadamias, mounds can be spaced as much as 15 m apart; for smaller shrubs such as coffee, mounds may be as little as 3 m apart, depending also on crop variety. Older varieties of apples were traditionally planted up to 10 m apart but modern varieties, cultivated on dwarf rootstock, may be planted only a few metres apart.

In North Queensland, the most common spacing for single row bananas was initially around 4.5 m, but to reduce shading, encourage more grass growth and improve flexibility with mound direction, rows are now around 5–6 m. However, as noted above, cross-slope mounds on steeper slopes require longer batters resulting in greater distance between mounds. For up-and-down slope mounds the only limitation is the amount of soil required for an adequate height of mound (Figure 12.19).

Figure 12.19: Height for up-and-down slope mounds varying with batter slope and row spacing



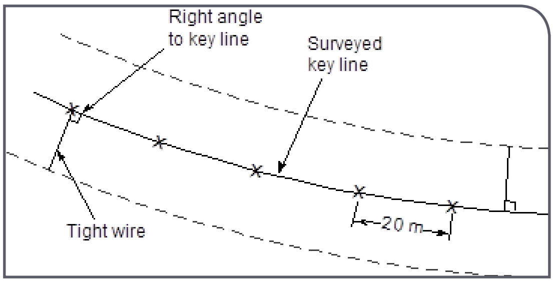
Laying out mounds

Marking out of mounds should be undertaken before any earthmoving works commence, and should not be just done just by eye. For up-and-down slope mounds less care is needed as an adequate gradient is automatically assured. However, for cross-slope mounds more care is necessary to ensure the gradient allows runoff to discharge appropriately. That is, there should be no reverse gradients that either cause ponding within the mound layout or cause runoff to discharge away from the nominated disposal areas. Correction bays requiring the surveying of a new key line may be required to address unsuitable gradients.

The following steps may be used to mark out a cross-slope mound layout:

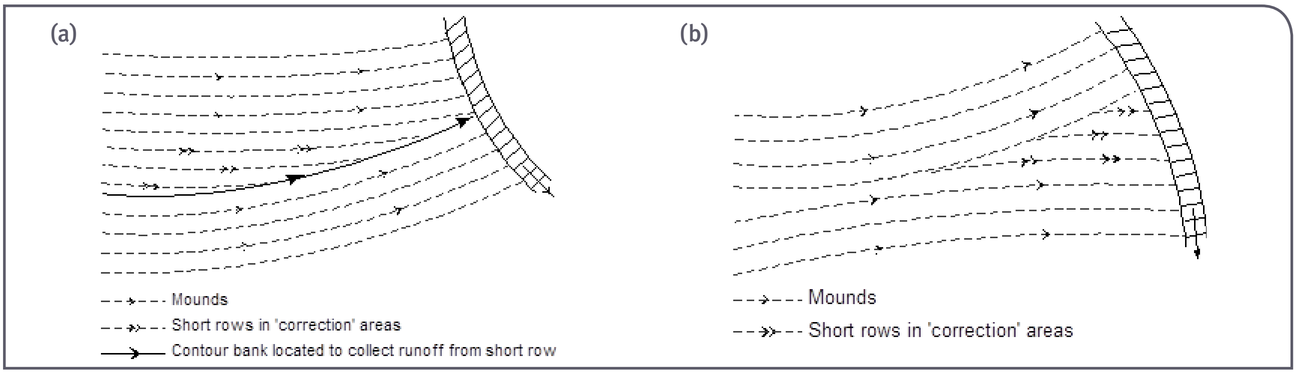
1. Use a survey level to locate a key line (Figure 12.20). This key line may be within the proposed block, or in a diversion bank at the top of the block. Depending on topography survey points should be every 10–20 m; the closer spacings required for complex, tortuous landscapes.

Figure 12.20: Marking out parallel rows across the slope



2. Mark out successive mounds parallel to the key row using a wire or cable tightly stretched out between two people and at right angles to the key line. Depending on row/mound spacing a longer cable may allow several parallel rows to be marked simultaneously.
3. Carry out periodic surveys on selected parallel rows—say every fourth or fifth row—to ensure that gradients are appropriate.
4. Survey a new key line where the check survey indicates gradients are either too steep or too flat. This will identify a 'correction strip' where short rows will need to be established (Figure 12.21).

Figure 12.21: Parallel mounds for: a) converging layouts ; and b) diverging layouts (adapted from van Putten 1985)



Note that mounds within a correction strip will discharge into a mound (or diversion bank), or a waterway, or other natural stable feature depending on the topography. Where rows are orientated to discharge from a low slope to a steeper slope, the rows will converge (Figure 12.21a); and will diverge where they discharge from a steep slope to a lower slope (Figure 12.21b).

It is possible to mark out a key line using a tractor mounted differential GPS system, and then for checking every fourth or fifth line by using the GPS and progressively checking the height and gradient. If necessary, a dumpy level can be used to check if gradients are appropriate. Most modern tractor GPS units will measure altitude, or land height, but often this feature is not switched on in the standard software install. Enabling this feature will allow field levels and contours to be easily mapped and be an aid to overall drainage design.

Aligning up-and-down slope mounds using GPS is relatively straightforward compared to that for cross-slope mounds. A key row is located perpendicular to the natural contour and then subsequent lines are marked parallel to it on either side. As rows become more distant from the key row they may start to diverge from directly up and down the slope. However, provided acceptable gradients allow for continuous drainage, this should not cause any problems. Often the key line can be located in the middle of a block; depending on topography, however, other options may include parallel to a boundary fence, an internal access or a drainage line.

Constructing mounds

Mounds can be constructed with a tractor-mounted blade, bulldozer or a V drainer; graders are suitable in straightforward situations, and disc ploughs for building relatively small mounds. Bulldozers are recommended where large mounds are required and where there are stumps, rocks and broken or steep ground. Prior to construction, old wash lines that will not be used for waterways should be filled and levelled; deep ripping will facilitate earthmoving and will break up hard soil layers.

Constructing up-and-down mounds is relatively simple as less earthmoving is required and less attention is required ensuring drains have adequate gradient. Where mound length is excessive, however, it may be necessary to install additional cross-slope banks or drains to reduce the risk of erosion.

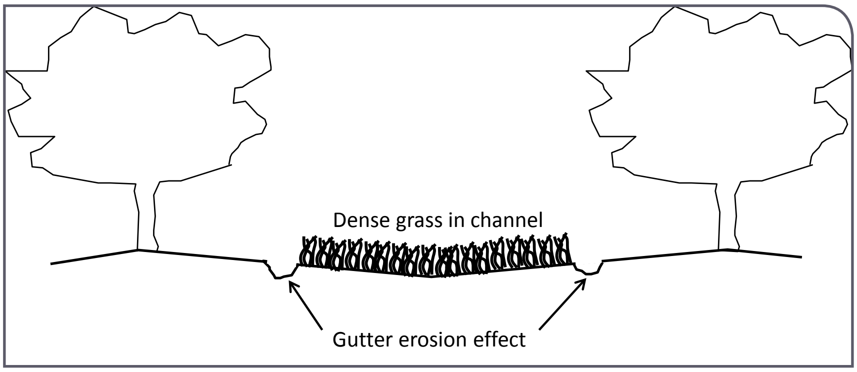
On steep land (>15%), cross-slope mounds are more difficult to construct as wider row spacings may be necessary to ensure mound batters are not unacceptably steep and susceptible to erosion.

Following construction, bare areas should be protected by a cover crop or a grass-legume sward as soon as possible. Some additional topsoil may be required in runoff flow channels to ensure a quick, effective cover can be established. Dispersive soils should not be disturbed, but where unavoidable they should be redressed with non-dispersive topsoil. Where a cover crop has been sown over a whole block, the row lines for the plantation crops can be sprayed with a herbicide prior to planting or mulched with a suitable material to control groundcover competition.

Maintaining mounds

The inter-mound area should be well protected with vegetation cover to prevent erosion, especially for up-and-down slope mounds, and then slashed regularly to facilitate flow of runoff water. Excessive growth will restrict the flow and may divert runoff onto the bare areas under the trees resulting in 'gutter' erosion paralleling the inter-row strip (Figure 12.22). As the trees grow, the inter-row area can become shaded depending on aspect, row orientation and spacing. Use of shade-tolerant species such as sour grass or sweet smother grass can safeguard against a loss of value of the cover. Care should be taken to ensure wheel traffic, or smothering by leaf trash, does not reduce the efficiency of the vegetation cover.

Figure 12.22: Gutter erosion effect due to excessive grass growth in inter-row strips



Access can be a problem when maintaining mounds. Cross-slope mounds are generally easier to traffic in wet weather, although slippage may occur on the down-slope side of batters on steeper slopes (e.g. >15%). Access for up-and-down slope rows can be even more hazardous in wet weather conditions and may sometimes be possible only with a four-wheel-drive tractor or crawler.

In an existing plantation or orchard where localised erosion problems are occurring, it may be necessary to install or replace mounds. Placing soil around the stems/trunks of existing crop trees—particularly macadamias—is not generally recommended. However, for some plantations it may be possible to construct mounds in parts of the layout where problems are occurring.

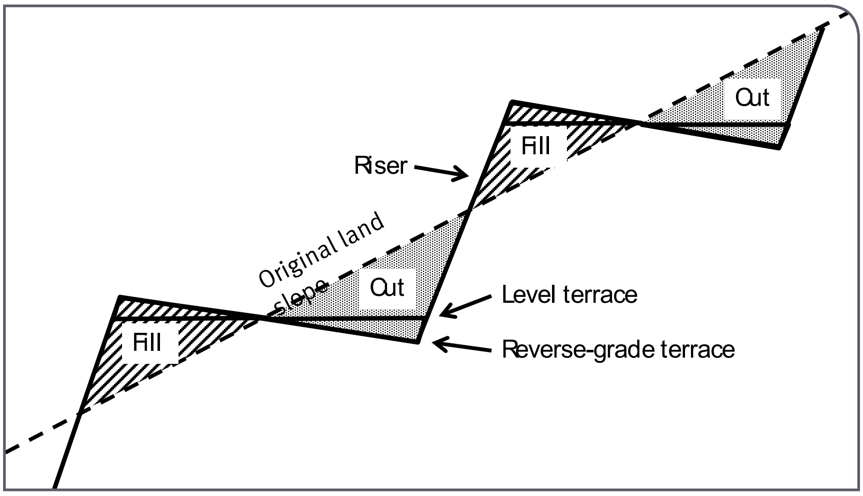
Where tree rows are too narrow or the trees are sensitive to soil disturbance, an alternative may be to strategically remove some trees to allow for the construction of contour banks.

12.4.6 Managing runoff with terraces

Terraces are used to convert very steep land into a series of benches running across the slope (Figure 12.23). The benches can be level or can have a reverse fall that allows drainage to the back batter. They are separated by steep risers that are usually stabilised with materials such as rocks or stones or with grass. If the risers are less than 1 m high, and the soil is a stable type, such as a ferrosol, it may be possible to make them near-vertical without the need for specific stabilisation.

Bench terraces have been used for many centuries, in some countries on slopes greater than 15%, and mostly using manual labour. Level bench terraces are often used as rice paddies by adding a small dike on the edge of the bench to impound water. In areas on steep slopes west of Gympie, terraces with 3 m widths were used to cultivate bananas and papaw with one row of plants per terrace. They are now rarely used in Queensland, as most horticultural cropping is carried out on land less than 15% slope where other measures such as mounds are more appropriate and are cheaper to construct and maintain.

Figure 12.23: Cross-sectional view of a set of bench terraces on a steep slope



Bench terraces are only suitable where the topsoil is deep and soils are not dispersive or overlying rock. Their construction requires a large amount of cut-and-fills, ensuring that the 'cut' section does not expose comparatively infertile subsoils. It is also important that the fill section consists of a stable soil, well compacted so that it does not subside or become prone to landslip in wet conditions. The wider the terrace, the greater the amount of earthworks is required, and the greater the construction costs will be. Difficulties associated with harvesting crops from a lower terrace also limit the use of bench terraces.

12.4.7 Managing runoff with in-field interception structures

Contour banks, contour drains or cross-drains are the most common in-field structures used to intercept runoff as it flows across a cropped area and divert it to a safe disposal area such as a grassed waterway.

Contour banks

Contour banks are permanent earthen structures constructed at intervals across the slope to intercept and divert runoff from a cropped area into a stable grassed watercourse (see Chapter 9 for detail). Contour banks are only practical for use on moderate slopes (less than 12%), as banks on steep slopes have very little capacity and the steep batter created to build the bank is vulnerable to erosion.

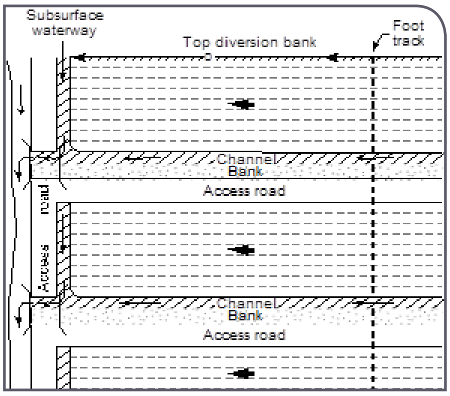
Rows of horticultural crop on slopes of less than 5%, can be angled across the slope or run directly up-and-down slope, to discharge either into a stable disposal area or into the contour bank channel (Figure 12.24). The row length and soil erodibility need to be considered when planning a layout. A detailed topographic survey is useful for assessing the most suitable layout.

Figure 12.24: Plan view of pineapple plantation with up-and-down slope rows draining into contour banks

For horticultural enterprises where row cropping is the norm, crops are usually planted on hilled rows to improve drainage, and these rows carry runoff to a subsurface waterway that may then discharge into the contour bank or to an adjacent main waterway. The contour bank channel may only carry runoff at the time of a high-rainfall event that may cause the hilled rows to overtop, or in the fallow period between harvesting one crop and sowing or planting the next crop. In these circumstances, parallel, across-the-slope layouts (Figure 12.25) function best. Criteria provided in Section 12.4.4 concerning control of erosion in raised beds is relevant to suitable layouts for managing runoff from rows.

Straight rows are preferred for inter-row cultivation and spraying, as these are more difficult on curves. The use of relatively short rows and additional waterways improves the chances of obtaining a workable layout incorporating contour banks. The channels of contour banks may be used as lateral access tracks during dry conditions. Under wet conditions it is preferable to travel below the contour bank.

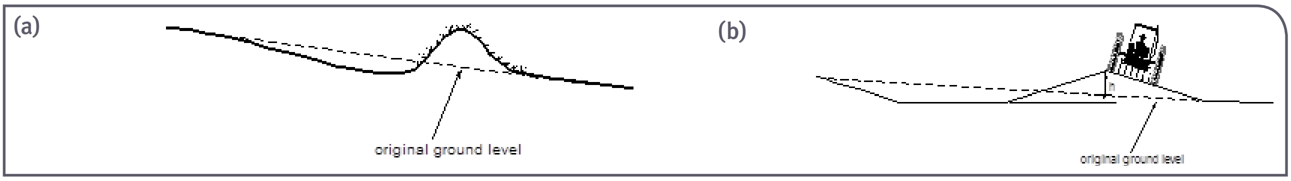
Figure 12.25: Plan view of a contour bank layout (Bierenbroodspot and Jamieson 1983)



Contour banks can be either narrow-based (Figure 12.26a) or broad-based (Figure 12.26b). The former are more suited to steeper slopes and shallower soils, and the latter to deeper soils on more gently sloping land, generally less than 5%.

Cross-slope access roads are best located immediately below the contour bank. Locating access tracks on top of a bank is not recommended as they may become destabilised.

Figure 12.26: Contour banks: a) narrow-based; b) broad-based



Recommendations for contour bank spacing are provided in Table 12.4. These were adopted for broadacre cropping, and depending on levels of surface cover in those areas, contour banks may be either single-spaced or double-spaced—see Chapter 7. For most horticultural situations single spacing is recommended, as cover levels are often minimal and higher bank gradients are normally used to improve drainage. Single spacing will also allow gradients to be manipulated to achieve a parallel layout and to improve compatibility with irrigation layouts.

Table 12.4: Recommended contour bank spacing

Average land slope (%)	Single spacing		Double spacing	
	aVertical interval (m)	aHorizontal interval (m)	aVertical interval (m)	aHorizontal interval (m)
1	0.9	90	1.8	180
2	1.2	60	2.4	120
3	1.5	45	3.0	90
4	1.6	40	3.2	80
5	1.8	36	3.6	72
6	1.9	32	3.8	64
7	2.1	30	4.2	60
8	2.4	30	4.8	60
9	2.7	30	5.4	60
10	3.0	30	6.0	60
>10	3.0	25	6.0	50

Note: a Vertical interval is the difference in height between the crests of adjacent banks; horizontal interval is the horizontal distance between adjacent bank crests.

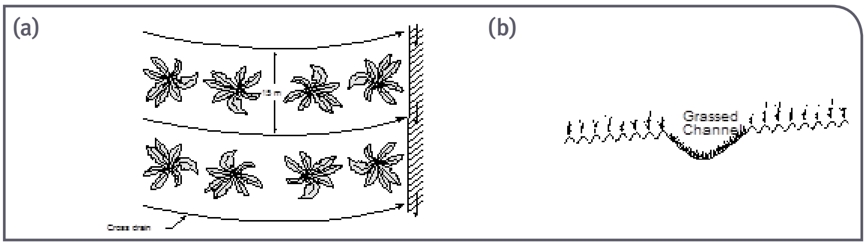
Depending on bank length, channel gradients of 1–5% can be used. The gradient of contour banks in horticultural situations can be steeper than those in broadacre cropping since contour banks in horticultural situations are usually much shorter. Higher gradients in contour banks will also ensure that drainage is not impeded and will consequently lessen the risk of waterlogging.

For contour bank gradients greater than 2%, the risk of erosion can be minimised by having parabolic or trapezoidal shaped channels that are not cultivated and are preferably vegetated. These higher gradients are more appropriate at the upper end of contour banks where there is less runoff, and therefore lower risk of erosion, compared to the outlet end.

Contour drains and cross-drains

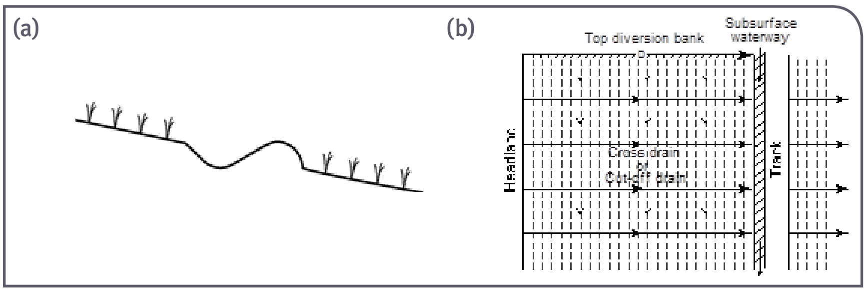
For landscapes where mounding to improve soil depth is not required, 'flat planting' is appropriate, but may require low-capacity contour drains across the slope to control erosion (Figure 12.27). These are suitable for crops such as papaws, bananas and tree crops where there is an adequate soil depth on moderate land slopes (2 to 8%). Contour drains are usually constructed with gradients of 2 to 5% with a single pass of a disc or mouldboard plough and soil thrown downhill. Maximum excavation depth is about 20cm, and the maximum spacing normally about 15 metres (Figure 12.27a). Gradients of up to 5% are acceptable provided the channel can be vegetated.

Figure 12.27: Contour drains: a) plan view, banana plantation; b) cross-section, small crops



Cross-drains or cut-off drains (Figure 12.28) are used on steep slopes, up to 25% where the crop rows run up-and-down slope. These are particularly applicable to short-season vegetable crops such as beans and strawberries, where harvesting is generally by hand and picking upslope reduces back strain. The cross-drains intercept runoff from the rows and convey it to a safe disposal area such as a grassed waterway or drain that would normally be subsurface (Figure 12.28b). For up-and-down slope rows on steep slopes, and especially in the early stages of the crop where ground cover is minimal, the risk of erosion is alleviated by installing cross-drains.

Figure 12.28: Layout with cross-drains or cut-off drains: a) cross-sectional view; b) plan view



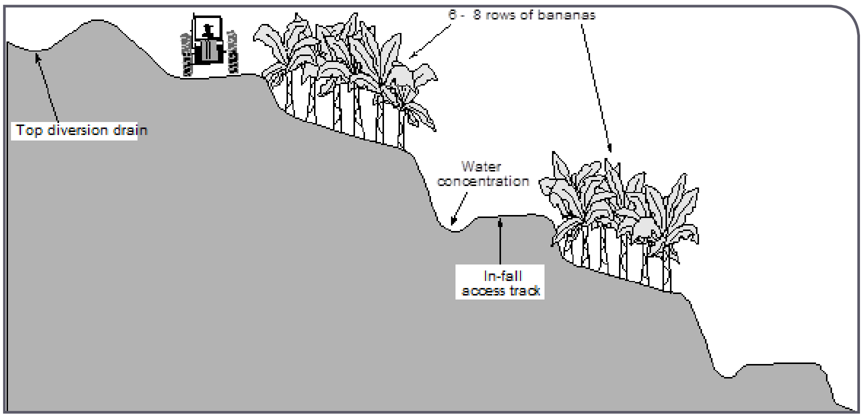
Cross-drains are usually temporary, built after a crop is planted and ploughed in when preparing for the next cycle. They are built using a single pass of a disc or mouldboard implement with the soil thrown to the downhill side. The gradient in the drains may be 2–5%, usually spaced 10–20 m apart (with the closer spacing used on the steeper slopes) and may be parallel, although this is not strictly necessary.

Cross-drains should be reinstated if their capacity has been reduced by inter-row tillage used for weed control, or after a rainfall event has resulted in soil erosion and silt deposition. The drains should be regularly inspected and sediment removed and bank/channel reshaped as required. Instead of a cross-drain, some potato farmers in southern states use an implement that opens up a slot in the soil on the contour and places a 'biscuit' cut from a bale of hay to create an obstruction to runoff. This technique has not been used in Queensland but it is likely to be less effective under the much higher rainfall intensities typically experienced in this state. The technique might even result in higher erosion rates when the structure inevitably 'fails', leading to concentrated flows of runoff ponded by the hay biscuit.

Access tracks

In-fall access tracks (Figure 12.29) are a variation of a bench terrace, somewhat similar to a contour bank. These tracks are used in growing bananas and papaws on slopes steeper than 15% in southern Queensland and northern New South Wales. Parallel drains allow runoff to concentrate along the inside edge of the track, providing a stable surface for vehicle access on the outside of the drain. Angled drains, or 'mitre-drains', should be constructed at frequent intervals to safely divert runoff away from the track. The tracks are parallel and normally spaced at about 20–25 m down the slope, or about six rows of papaws or bananas. The tracks allow misting or harvesting to be carried out, but access to the mid rows may be restricted for effective spray operations.

Figure 12.29: In-fall access tracks in a banana plantation



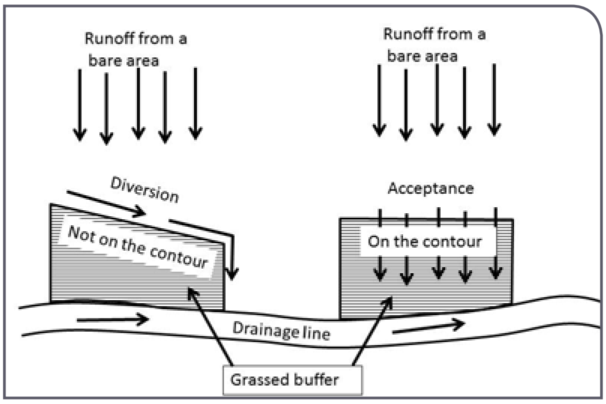
It is recommended that in-fall tracks be constructed on gradients of 1–3% to ensure the structures can carry generated runoff at a non-erosive velocity. If erosion is occurring, additional protection can be provided by establishing vegetation in the drains or by retaining crop mulch in situ. An appropriate ground cover should also be sown on the steep slope above the drain if it is at risk of eroding.

12.4.8 Managing runoff with vegetated strips

Correctly positioned, vegetated buffer strips between or below horticultural crops can filter runoff containing sediment and nutrients before it enters a watercourse. To be an effective filter, the strips should be placed at spacings similar to that shown for contour banks in Table 12.4. Suggested widths for grassed areas receiving runoff from production areas relative to slope, soil type, rainfall and region are tabulated in Karssies and Prosser (1999). Recommended widths vary from >30 m for situations with poor cover and with highly erosive rainfall as in the Wet Tropics, to around 2 m for situations with good cover and less erosive rainfall as in south-east Queensland.

As runoff will always take the easiest pathway, it is essential that rills be levelled before sowing, and that the upslope edge of a strip is on the true contour and is continuous without breaks. A vegetated strip that is not on the contour will divert and concentrate runoff from bare areas above it (Figure 12.30).

Figure 12.30: Vegetated strips placed on the true contour to filter sediment and nutrients

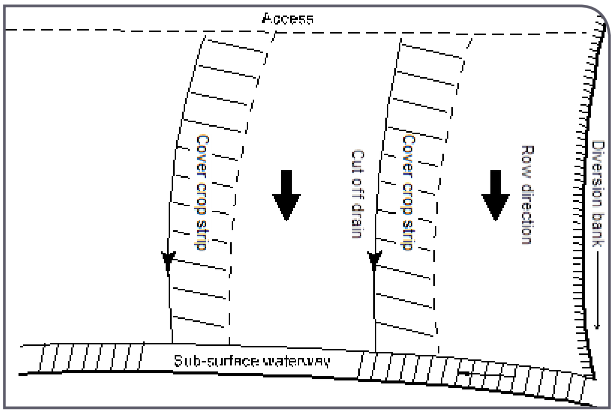


Although runoff often flows in sheets downslope towards drainage lines, it does not enter watercourses as a wide shallow flow over the banks. Rather, it concentrates as it moves towards a stream, entering in concentrated flows at defined points through the bank and not as a broad sheet. Consequently, while riparian vegetation has many benefits it does not generally act as a filter for runoff flowing from adjacent catchments. To protect water quality in the stream, ground cover must be maintained over the whole of an agricultural catchment, and the runoff needs to be managed so that it enters streams via well vegetated channels.

A vegetated strip on the contour can be used in conjunction with of a cut-off drain located at the downslope edge of the strip (Figure 12.31). The cover crop can either be planted as strips or over the whole block. For the latter, once established, strips of the cover crop can be removed by cultivation or spraying, and the area planted to vegetables. The strips may be used as headlands, or access to adjoining strips of crop, as well as trapping any sediment from the upslope cultivated area. The spacing between cross-drains can be increased if used in conjunction with vegetated strips.

As the cross-drains are temporary, the location of these strips is flexible and they can be moved to suit the fallow management program of the farm. Strips may be used with cross-slope rows (Figure 12.31), or they can be used for up-and-down rows with implements being lifted as they cross the strip.

Figure 12.31: Use of vegetated strips and contour drains for erosion control



Erosive flooding in broadacre crops is controlled on the Darling Downs floodplains by strip cropping that involves sowing alternating strips of crop at right angles to the direction of the flood flows. The aim of strip cropping is to reduce flow velocities by having floodwaters spread out to dissipate their energy rather than to concentrate them. Strips should be coordinated across properties on the floodplain, as otherwise flood flows may be diverted onto land that does not have strips where it can concentrate and cause erosion problems.

Strip cropping may be applicable to horticulture under some circumstances, although to be effective the crop species or variety needs to have a high capacity to resist flood flows, as is provided by broadacre winter and summer cereal crops. Also, as horticultural enterprises on the floodplains are usually relatively smaller properties, it may be less practical to coordinate strips between large numbers of properties that are growing a range of different crops.

12.4.9 Managing runoff with sediment traps

Passive treatment measures that incorporate sediment traps and artificial wetlands are increasingly being used to treat water leaving intensive horticultural properties. Runoff water can contain a mix of sediment, nutrients and chemical residues that can be damaging to the environment. A sediment trap is often the first stage of passive treatment after the other measures described above have been implemented.

A sediment trap is a basin that removes heavy sediment and litter from runoff water by allowing it to settle out and be left behind when the water moves on. A sediment trap needs to be designed to allow easy access, so that the trapped material can be removed for disposal after it has settled out. Intensive farming systems that often have a high use of phosphate fertilisers can have high levels of phosphates attached to sediments in runoff water. Some of this phosphorus can be removed by capturing the sediment in a modified phosphate filter trap that incorporates lime-enriched sand.

To remove fine sediments, dissolved nutrients and chemicals, runoff water leaving a sediment trap should be passed through a series of filter beds and constructed treatment wetlands. Physical and biological processes remove these contaminants progressively before it is released to the environment or reused.

12.5 Monitoring

Monitoring a horticultural layout after a rainfall or runoff event is an important function of effective erosion control. Much can be learnt by inspecting how a layout has performed during and after significant rainfall events. Records should be kept of the rainfall amounts and rates and of other factors such as the landuse condition of contributing catchment and the capacity and condition of runoff control structures at the time of a runoff event. The condition, amount and height of vegetation in a channel, and depth of flow at various locations should be assessed in relation to amount and intensity of rainfall and runoff. Such monitoring can identify current and future erosion risks in a horticultural layout, indicating where preventative maintenance or remedial action is required.

12.6 Further information

References

Akehurst, A, Newley, P and Hickey, M (2008) *Soil and water best management practices for NSW banana growers*, Department of Primary Industries, State of New South Wales.

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van Putten, J (1985) *Mounds up and down slope reduce the risk of frost*, Technical News, Soil Conservation Branch, Department of Primary Industries, Brisbane.

Other information

Fact sheets

Available online from the websites of the various organisations listed.

1. Queensland Government Science Notes—Soil and Land Management:
   - Erosion control on property roads and tracks - cross-sections and locations
   - Erosion control on property roads and tracks - managing runoff
   - Soil conservation waterways - Plants for stabilisation

(searchable at ‹publications.qld.gov.au/dataset/science-notes-soil-and-land-management›, accessed 29 July 2015)

2. New South Wales Agnote series:
   - DPI-382, Sweet smothergrass—a perennial ground cover for subtropical orchards.
   - DPI-332, Amarillo peanut—a perennial ground cover for subtropical orchards.

(searchable at ‹ dpi.nsw.gov.au/aboutus/resources/factsheets/agriculture› (accessed 29 July 2015)

Technical reports

Reports available for download as PDF files from the EHP (formerly DERM) library catalogue (searchable at ‹https://www.qld.gov.au/environment/library/› (accessed 29 July 2015) , including the series of Land Management Field Manuals and the series of Understanding and Managing Soils produced by the former DPI Soil Conservation and Land Resources branches for the following:

- Moreton Region
- Stanthorpe–Rosenthal Region
- Waggamba Shire
- South-East Darling Downs District
- Central Darling Downs
- Crows Nest District
- Murilla, Tara and Chinchilla Shires
- Roma District
- Wandoan District
- Roma District
- Coastal Burnett Districts
- Inland Burnett Districts
- Central Highlands
- Atherton Tableland
- Mareeba District

Guidelines

Queensland Department of Agriculture, Fisheries (DAF) publications available on line (searchable at ‹dpi.qld.gov.au/extra/era› (accessed 29 July 2015):

- Avocado information kit
- Banana root and soil health user's manual
- Brassica information kit
- Capsicum and chilli information kit
- Macadamia growers handbook (reprint of a 2004 publication)
- Mango information kit
- Papaw Information kit
- Rockmelon and honeydew information kit
- Strawberry information kit

- Strawberry: best soil, water and nutrient management practices
- Subtropical banana information kit (reprint of a 2004 publication)
- Tropical banana information kit

Department of Primary Industries NSW publications online:

- *Saving soil—A landholder's guide to preventing and repairing soil erosion* (available at ‹dpi.nsw.gov.au/agriculture/resources/soils/erosion/saving-soil› accessed 29 July 2015)
- There are 11 separate publications and two YouTube videos available at this address that could be useful: ‹dpi.nsw.gov.au/agriculture/resources/soils/erosion› (accessed 29 July 2015)

AusVeg Ute Guide: Healthy soils for sustainable vegetable farms ‹ausveg.com.au/enviroveg/ausveg_soilhealth_ute_guide_a5_bw.pdf› (accessed 29 July 2015)

Freshcare—Environmental code of practice (2nd edition) ‹freshcare.com.au/downloads› (accessed 29 July 2015)

Guidelines for environmental assurance in Australian horticulture: Chapter 1—Land and soil management ‹hoho3216.staging-cloud.netregistry.net/environmental-assurance-guidelines/chapters/land-and-soil-management/› (accessed 29 July 2015)

Healthy Country sustainable land management resources: A number of reports relevant to horticulture, including best management practice and benchmark reports, can be found at: ‹healthycountry.org/HealthyCountry/Resources/SustainableLandManagementResources.aspx› (accessed 29 July 2015)

Soil health BMPs for various north coast New South Wales industries contain some soil erosion control advice (searchable at: ‹northcoast.lls.nsw.gov.au›, accessed 29 July 2015)

Scientific reference material

Alt, S, Jenkins, A and Lines-Kelly, R (2009) *Saving soil: A landholder's guide to preventing and repairing soil erosion*, NSW Department of Primary Industries (no print version currently available but can be downloaded at ‹dpi.nsw.gov.au/agriculture/resources/soils/erosion/saving-soil› accessed 29 July 2015).

Sheng, TC (2002) *Bench terrace design made simple*, Proceedings of the 12th International Soil Conservation Conference, Beijing, 2002 ‹tucson.ars.ag.gov/isco/isco12/VolumeIV/BenchTerraceDesignMadeSimple.pdf› (accessed 29 July 2015).