Strawberry

best soil, water and nutrient management practices

Queensland Government
Department of Primary Industries and Fisheries

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A guide to better soil, water and nutrient management practices for the south east Queensland strawberry industry

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Department of Primary Industries and Fisheries, Queensland

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The Department of Primary Industries and Fisheries (DPI&F) seeks to maximise the economic potential of Queensland's primary industries on a sustainable basis.

This publication has been compiled by Zane Nicholls, Ian Layden, John Bagshaw and Brian Stockwell DPI&F Regional Delivery Group, South East Queensland and Lourens Grobler, Industry Development Officer, Queensland Strawberry Growers Association.

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Acknowledgements

The authors gratefully acknowledge the use of the Victorian DPI publication 'Improving environmental management. A guide to better soil, water and nutrient management practices for the Victorian strawberry industry.'[1]

Case study growers: John Carmichael, Terrance and Nathan Roy, Rick, Jeff and David Twist, Luigi Coco and Ray and Kim Daniels.

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FarmFLOW
growth through good practice

[1]This publication carries the following disclaimer: 'This material may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or consequence which may arise from your relying on any information contained in this material.'

Foreword

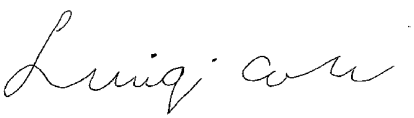
The Queensland Strawberry Growers Association is committed to supporting healthy, thriving and viable businesses by promoting research, tools and activities which address best practice and improve farm profitability.

With climate change, water availability issues, and the possibility of environmental policy change combined with a rapidly growing population it is important that our industry achieve improvements in water usage, soil and nutrient management while at the same time demonstrating to markets as well as the broader community that our industry is practising responsible farm management.

Best practice plays an important role in achieving these outcomes and these guidelines were formulated to ensure that they include the practices which address the needs of producers.

I believe that the industry will benefit from the application of these guidelines by equipping producers with both practical and sound management practices that will lead to better outcomes for soil health, nutrient inputs, water use efficiency and integrated pest management. This combination of practices will assist producer's to achieve profitability and long term sustainability.

The Queensland Strawberry Growers Association endorses the practices outlined in this document and encourages all strawberry producers to adopt them on their farm. These practices will demonstrate industry commitment to sustainable land practices while also enhancing the quality of our product and local waterways for future generations.



Luigi Coco

President, Queensland Strawberry Growers Association, Australia

Introduction

In recent years there have been significant advances in our knowledge of plant breeding, integrated pest management and nutrient management for strawberry production in south east Queensland.

Many producers have taken up the challenge of using continuous improvement programs to move toward more precise methods of farming. This publication aims to provide practical advice to growers so the industry as a whole can meet consumer and government expectations and their own goals for their enterprise.

Ninety-five percent of Queensland strawberries are grown in the coastal region between Brisbane and the Sunshine Coast. Much of this region drains into Pumicestone Passage and Moreton Bay – an area listed internationally as a wetland worthy of protection. It has significant recreational value and commercial fishing and other water-based activities. It is also home to large numbers of migratory birds.

The quality of water draining into this area is therefore of great community concern. Nutrients, soils and other contaminants polluting these waterways can affect marine life, contribute to toxic algae outbreaks, and have led to permanent harvest restrictions for local oyster leases.

The risk of soil and nutrient loss in water runoff from horticultural properties, in many instances, is influenced by factors that are under the control of the farm manager. For example, soil cultivation practices influence soil structure and the incidence of soil compaction, water runoff and soil loss. Irrigation management practices influence the amount of water runoff. The extent of vegetative cover on a property influences soil loss. Other factors, such as storm events, are beyond the control of the farm manager and at times, runoff is unavoidable.

This booklet focuses on the fundamental principles of preventing soil and nutrient loss by:

- applying nutrients in the right form, with correct application rates and timing, using recommended methods
- maximising the uptake of nutrients by the crops they are applied to
- maximising infiltration of water where it falls
- maximising soil cover
- reducing the amount of ‘external’ runoff flowing through an area under production
- safely removing surface water in the event of runoff.

While the practices outlined are essential to 'good environmental management', they also complement sound farm business management decisions. Like other businesses, horticulture have a duty of care to ensure they do not harm the environment (e.g. contribute to waterway pollution). At a personal level, growers have enjoyed fishing and boating on coastal waters for generations and want to protect the area for their children to enjoy.

Meet the growers

This guide features five strawberry growing businesses. These growers are well-respected for their knowledge and sustainable production practices. Throughout this guide you will find examples of their management practices.

Twist Berries – Rick, Jeff and David Twist are third generation farmers operating the family farm at Chevallum. They have built the farm up to the standard it is today through hard work and 'good honest farming practices'.

A & E Coco and Sons – The Coco family began growing strawberries at Elimbah 25 years ago. They usually plant 20 hectares of strawberries and have trialled and implemented many traditional and innovative farm practices. Luigi and John manage the farm's day-to-day operation.

Strawberry Fields – The Carmichael family farm is at Palmview. John Carmichael grows strawberries using many natural products to reduce external inputs. The farm is exceptionally well presented with lovely gardens and picnic areas for customers to enjoy.

Sunray Strawberries – Ray Daniels has 36 hectares under strawberry production at Wamuran. He established the farm using the current best management practice tools.

Coolhaven Farms Pty Ltd – Terrance and Nathan Roy are the third generation on their family property at Beerwah. They recently took over management of the farm from their father.





1. Soil structure and its protection

Good soil structure is vital for maximising soil water intake and plant growth and minimising soil erosion.

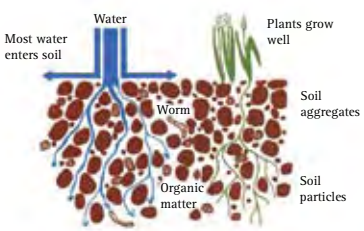
Red soils, formed on basalt parent rock, are inherently well-structured but this structure can be damaged by improper management. Soils formed on sedimentary rock – generally grey soils – tend to have a weaker and even more easily damaged structure.

Well-structured soils have a high proportion of water-stable aggregates (large clusters of soil particles) which are held together by electro-chemical properties and the resins and gums of organic matter. Bigger pores or air-filled spaces exist between individual aggregates of a well-structured soil. These pores remain open to receive water and nutrients and as a result, less water runs off the soil surface and plants thrive.

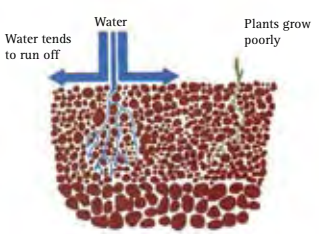
Water droplets hitting exposed soil

Larger raindrops in still air hit soil surface aggregates at 30 km/hour and faster if it is windy. Each raindrop blasts individual soil particles upwards and sideways. This effect can easily be witnessed after a heavy storm when fence posts, machinery left in the paddock and even strawberry fruit, are covered by a film of soil particles. On falling back to the soil surface, these individual soil particles fill the pore spaces, which were once open to air and water, forming a crust that impedes water infiltration and increases the volume of runoff.

If the soil is covered with vegetation or mulch, raindrops are intercepted and soil particle detachment and splash are avoided.



Good soil structure



Poor soil structure

Source: Caring for Cultivated Soil, 1991

Poorly-structured soils are at greater risk of damage from water droplets and water runoff.

Water runoff

When water, either as rainfall or irrigation, falls faster than the soil can absorb it, it begins to flow over the soil surface. Flowing water, particularly when concentrated down bare slopes, has the potential to pick up and transport detached soil particles and associated nutrients.

> The transport of soil in flowing water can be minimised if the water flows over stable drainage ways.

REMEMBER: It is the size and number of pores between aggregates of individual soil particles that determine the ease with which a soil can absorb and transport water, nutrients and air to the roots of plants. Damage to soil structure reduces the size and number of large pores and therefore directly reduces the potential productivity of a soil. To promote good soil structure, particular care must be taken to minimise aggregate breakdown and maximise organic matter levels.

Ripping plays an important role in breaking up compacted layers or hard pans below the soil surface and enhancing water infiltration.

1.1 Cultivation practices

Frequent cultivation, faster tractor ground speed and heavy machinery all contribute to the destruction of soil aggregates and the break down of soil stabilising organic matter. Working on soil that is too wet or too dry accentuates the problem.

Damage to the structure of soils can be observed when soils are dry. Soils that used to be soft and open can set as hard as a brick. To gauge the impact of any particular cultivation practice on your farm, compare worked soil to undisturbed soil, perhaps on a road reserve or under an old fence line.

The following will help to protect or improve soil structure:

- Reduce cultivations to the minimum essential number.
- Minimise the number of passes by combining operations such as hilling up and ripping wheel tracks.
- Avoid using heavy machinery on too wet or too dry soils. Cultivate when moisture content makes the soil feel friable – not wet and slippery when the soil sticks, or dry and hard so that it powders.

- Ripping can break up developing hard pans (compacted layers below the soil surface) which restrict water infiltration. Rip on the contour as part of initial ground preparation, when soils are moist and friable.
- Soils are most susceptible to erosion when at their finest tilth. Delay final cultivation until just prior to the preparation of beds.
- Local experience suggests that running a roller over recently cultivated soil reduces the erosion hazard associated with rain events occurring shortly afterwards.
- Narrow compacted wheel tracks channel water and contribute to erosion. Reduce the impact of wheel tracks between rows by using radial or wider tyres on tractors and implements and by ripping wheel tracks.
- Work the soil to move it up the hill to avoid soil build-up at the bottom of slopes (i.e. either plough across or up hill).
- Consider implementing a minimum tillage farm system.

1.2 Green manure crops

Decomposing plant material or organic matter produces gums and resins which assist in binding soil particles together to form aggregates and pore spaces. This increases the water and nutrient holding capacity of the soil.

Green manure crops produce large quantities of organic matter over a short period of time. They also shield the soil surface from 'bomb-like' rain drops and so protect it against structure damage, soil erosion and nutrient loss. Green manure crops

Incorporating a green manure crop provides valuable organic matter that improves soil aggregate stability and structure along with the water and nutrient holding capacity of the soil.

also introduce nutrients, can break disease cycles and provide competition against weeds.

Cereal crops such as sweet sorghum, millet and maize (corn) produce bulk and organic matter. Legume crops fix atmospheric nitrogen and convert it to a form useful to the green crop and subsequent strawberry crops. To get the benefits of both, cereal and legume crops can be grown together (e.g. sweet sorghum and cow pea, maize and cow pea). Consider:

- Growing green manure crops in between successive strawberry crops.
- Slashing green crops before flowering to minimise seeding, encourage density and avoid weed problems.

Table 1 – Green manure crops suitable for spring sowing in southeast Queensland.

Crop	Nitrogen fixing	Min. growing period (months)	Sowing rate kg/ha	Comments
Cow pea	Yes	2.5-3	**17-35	Sow spring/summer, deep sandy soils, some varieties (red caloona and Holstein) offer resistance to phytophthora root rot. Aids establishment of beneficial soil micro-organisms
Pigeon pea	Yes	1.5-3	**20-35	Drought resistant, sandy to clay soils, aids establishment of beneficial soil micro-organisms. Resistant to the root lesion nematode. Pigeon pea is a small shrub and is best incorporated with grasses, not as a stand-alone crop.
Millet (Jap, white, French)	No	2-2.5	25	Sow spring. All millet cultivars are resistant to root-knot nematodes. The French variety has shown the greatest resistance.
Hybrid sorghum (sweet, forage)	No	2-3	20-30	Sow spring. Jumbo and sweet sorghums have shown a high resistance to root-knot nematodes.
Maize (corn)	No	3	15-20	Sow late spring/summer. Possible host to root-knot nematode

**Legume seed should be inoculated with the correct Rhizobium bacteria to ensure root nodules that can fix nitrogen and for vigorous plant establishment.
Source: Gardner and Morgan, 1993; Mullen, Holland and Hueke, 2003.

2. Fertiliser, irrigation, chemical and integrated pest management

Nutrients enter waterways attached to soil particles, or dissolved in water runoff. Dissolved nutrients in water can also leach to ground water. To maximise plant uptake of nutrients and minimise nutrients entering waterways or groundwater, actions that reduce water runoff and soil erosion, and maximise plant uptake of applied nutrients, are essential.

2.1 Fertiliser decisions and application

Nutrients such as nitrogen, phosphorus and potassium are essential for strawberry plant growth and fruit production. However, application of excessive nutrients can be both detrimental to the environment and the production of quality fruit, and is of course a waste of money.

Nitrogen and phosphorus in dams, streams and rivers result in excessive water weeds and/or algal growth and degradation of aquatic habitat. Over-fertilisation of strawberry plants with nitrogen can lead to excessive leaf growth which has implications on fruit yield, fruit firmness, fruit ripening, the effectiveness of applied sprays and disease control.

The following will assist to improve fertiliser use efficiency:

- Base fertiliser decisions on soil test, leaf analysis and plant sap test results that take account of soil type and varietal differences. Leaf analysis and plant sap testing should be conducted throughout the critical flowering to fruiting period. A nutrient monitoring

These Mottes tubes collect soil water that is used to measure the nutrients available to the plant within the root zone. These measurements also provide the grower information on how much nutrient is leaching beyond the root zone.

consultant can perform these complex tests for you. Seeking recommendations on application rates from your nutrient monitoring consultant over the growing and fruiting season enables the precise plant nutrient requirements to be applied.

- Keep fertiliser records to assist future fertiliser management decisions.
- Ensure spreaders are correctly calibrated prior to use.
- Band fertilising, or applying fertiliser to the top of prepared beds prior to planting is preferred to general broadcasting, as it delivers the fertiliser close to plant roots. If broadcasting is unavoidable, apply fertiliser as close to bed-forming as possible and incorporate it into the soil.
- Consider the use of banded, slow-release fertilisers. These fertiliser types extend nitrogen availability to the plant and reduce the nutrient leaching potential. Small scale farm trials will help identify the performance of these fertilisers under local conditions.
- Use fertigation (the application of dissolved fertiliser through a trickle irrigation system) to apply macro elements (nitrogen, phosphorus, potassium, calcium and magnesium). Applying nutrients close to the plant root zone during the growing period in this way, ensures plant nutrient uptake is maximised. Mottes tubes

Farmers on...
Nutrient management

John Carmichael from Strawberry Fields believes that regular nutrient monitoring has saved him money, assisted in producing a better crop and is beneficial for the environment.

'We presently use fertigation to apply our nutrients. The consultant determines the crop nutrient levels using soil solution tubes and leaf sap analysis to provide the nutrient recommendations.'

Terrance and Nathan Roy from Coolhaven Farms are using field monitoring equipment to help manage their crops.

'We wanted to maximise the nutrient we are applying so we have added a soil moisture monitor (CropSense) as a management tool. We like its efficiency as it provides constant updates of soil moisture, soil temperature and EC. This allows for precise irrigation and reduces the chance of over fertilising because we can apply it and keep it available where and when it is needed most – at the root zone.'

The **Twist brothers** are great believers in the benefits of chicken litter and have used it for many years. They understand the importance of proper storage of the chicken litter on-farm.

They use the correct stockpiling process where the pile is peaked to create a surface crust that reduces smell and water infiltration. They also believe in limiting the amount of time it is stored to a couple of weeks at the most.

'As part of our farm management we store the litter on a hard pan area that has generous grassed areas surrounding it and gently slopes towards a sediment trap.'

Ensure manure is stored to avoid contamination of surface water and groundwaters. Long term storage areas should be properly bunded.

are commonly used to extract soil water for nutrient analysis (testing).

- Restrict foliar applications of fertiliser to trace elements (boron, manganese, zinc and iron) unless specific macro deficiencies are evident.
- Apply several small applications of fertiliser during the growing season rather than single large applications to ensure maximum nutrient uptake.
- If bulk organic or inorganic fertilisers are used, they should be incorporated immediately if

A stockpile such as this should only be stored for the very short term as it lacks protection from rainfall and does not have a impermeable base. Long term storage will negatively impact on the native vegetation and seasonal melaleuca wetland just metres behind these chicken litter piles.

possible (e.g. chicken litter), or stored for the shortest time possible and as far from dams and water courses as possible. If stored, use the same carefully selected, dedicated storage area all the time and don't disturb stored heaps. Use a relatively impermeable site and minimise drainage movement into and from these sites by using diversion banks, cut-off drains and grassed buffers. Preferably protect the stored heaps from rainfall.

- Avoid spreading fertiliser near dams or watercourses.
- Do not apply fertiliser near native vegetation. Native vegetation prefers low fertility conditions.

Above: A combination of trickle irrigation (beneath plastic, also used for fertigation practice) and mister irrigation (above plastic). Right: A tensiometer in operation.

2.2 Irrigation methods

Irrigation is essential for strawberry production in south east Queensland, but over-watering can be as serious as underwatering. Too much water can cause soil compaction and water-logging, encourage root disease, reduce fruit quality and cause nutrients to leach beyond the root zone making them unavailable to the plant.

The following will help improve water use efficiency:

- Base the decision of when and how much to irrigate on soil moisture levels and plant requirements. This will ensure plant uptake is maximised and runoff to surface water and ground water minimised. Consider the use of soil moisture monitoring equipment (tensiometers) to assist irrigation scheduling and improve water use efficiency.

- Apply smaller volumes of water more frequently rather than occasional heavy applications.
- Trickle irrigation is the preferred irrigation method as it applies water close to the root zone and if managed well, results in zero runoff or seepage.
- Overhead sprinkler irrigation is used to assist the establishment of young plants or as a protection measure against frost and heat. In these instances, use micro-jets (misters) and use management techniques which promote good soil structure and which minimise the area of bare soil around strawberry beds. These techniques will ensure high rates of water infiltration and lower rates of runoff and erosion (see the sections on 'Soil structure and its protection' and 'Drainage management').
- Inspect regularly for damage to irrigation lines and ensure repairs are carried out promptly.

2.3 Chemical management

Chemical control

If your pest management decision was to do nothing but wait and see, chemicals are often the only realistic control option available. Crop monitoring enables you to select the most suitable chemical for a specific problem or combination of problems.

Factors that you need to consider when selecting a chemical control option are:

- the timing of application – the aim should be to target the most vulnerable part of the pest's lifecycle
- the ability to achieve good plant coverage, avoiding excess residues and off-site pollution
- irrigation scheduling
- the withholding period for the product, particularly if nearing harvest
- present and forecasted weather conditions
- whether the product registered for the specific pest
- resistance management – are there any regional resistance management guidelines current for your area?
- the likely impact on natural pest enemies. Beneficial insect populations are heavily disrupted by the majority of pesticides.

Chemical storage

Chemicals need to be stored in accordance with the AS 2507-1998 standard 'the storage and handling of agricultural and veterinary chemicals, in secure weather-proof containers with impermeable and bunded floors to limit theft, spillage into the environment, flooding or storm damage'. This does not mean you have to spend a fortune on elaborate storage facilities. You do, however, need to be aware of several safety,

Farmers on...

Integrated Pest Management

John Carmichael from Strawberry Fields says they employ a consultant to monitor crop pest levels and to provide recommendations on spray program.

'We have scout reports occurring every two weeks. The (consultant) report recommends when to spray and when to release predators into the plots. When we do spray we only target the areas where severe hot spots are reported.'

Terrance and Nathan Roy from Coolhaven Farms also use pest scouts to monitor pest levels on their farm.

'We believe in the simultaneous pest/predator release strategy for our IPM program. It has been a success to date and we'll continue down this path.'

A predatory mite, *Phytoseiulus persimilis,* can control two-spotted spider mite (right) infestations.

environmental and food safety factors whenever you deal with chemicals. Also consider the workplace, health and safety issues associated with chemical storage and handling.

Read the product label. It is a legal document and provides useful information on how best to use, handle and store the product.

2.4 Integrated pest management

The modern approach to insect pest control involves a reduction in chemical use and relying on a range of complementary control measures in an integrated program known as Integrated Pest Management (IPM).

The key elements to IPM are:

- the use of cultural control measures such as crop hygiene and crop rotation
- the use of biological control measures such as naturally-occurring or introduced parasites and predators of insect pests
- using chemicals only where necessary. Softer chemicals are preferred which are compatible with beneficial insects and reduce harm on the environment
- checking the crop regularly to determine when pests are present. This process of monitoring the crop to determine if and when control measures are needed can be done by yourself with some training or, as recommended, use a professional pest monitoring service.

Biological control measures

Nature provides many mechanisms for keeping a balance between pests and diseases. Working with nature is fundamental to Integrated Pest Management. With careful planning, an effective monitoring program, a good understanding of the cropping system and a willingness to tolerate some pest damage at times, it is possible to control problem insect pests within the farm.

Two-spotted spider mite (*Tetranchychus urticae*) and other mite species are the major pests of strawberries in Queensland. Control is achieved by utilising the predatory mite (*Phytoseiulus persimilis*) using the 'pest-in-first' or 'simultaneous release' systems, where spider mite infestations are initiated only to encourage the establishment of the predatory mites. By adopting this management option early in the growing season, protection against mites will remain high for the rest of the season. Other insect pests such as aphids, mealybugs, thrips, small caterpillars and whitefly are controlled by beneficial insects that occur locally such as brown (*Micromus sp.*) and green (*Mallada sp.*) lacewings and various ladybird species.

An IPM strategy utilises an array of beneficial insects like the assassin bug for strawberry pest control. An appropriate IPM strategy will lead to a reduction in pesticide use.

3. Drainage management

At times water runoff is unavoidable, and structures need to be put in place and management practices employed to ensure soil and nutrient losses are minimised.

Effort should go into:

- minimising the volume of external drainage affecting the site
- preventing irrigation/rainfall runoff from hitting or moving over bare soil
- creating 'safe' stable pathways that slow runoff water to a walk and allow any nutrient-laden sediment to drop out before it leaves the property or enters watercourses or dams.

Evaluating the need for and design of various drainage management strategies (cut-off drains, diversion banks, grassed waterways and sediment traps) or the performance of existing ones, is best done during rainstorms. It is the ideal time to check whether soil particles are moving, whether the rate of water production is greater than the capacity of drains, pipes, banks or waterways and whether intercepted water is being safely delivered to drainage lines and watercourses.

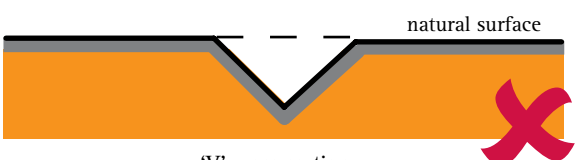
3.1 Grass headlands and buffers

Grass headlands and buffers are uncultivated strips of land sown to permanent grass. Situated above and below strawberry paddocks, they reduce the speed of and filter sediment from runoff water flowing down rows. At the end of the season, leave permanent headlands in place, do not rip across them.

A grassed headland and buffer strip between strawberry rows and natural drainage lines.

The following practices will help drainage management:

- Effective headland and buffer width is dictated by slope. The steeper the slope, the wider the headland or buffer will need to be.
- Place headlands and buffers across the slope where water is concentrated or flows over changes in gradient, around dams and adjacent to waterways and be restricted to slopes no greater than 10-15% (diversion banks should be used on steeper slopes).
- Sow headlands and buffers with perennial grasses that are maintained (slashed) to encourage deep rooting and dense and vigorous top growth. A swathe height of 15 cm is recommended for maximum filtration capacity. Suitable grasses include pangola, couch, kikuyu or carpet grass which can handle traffic, as well as wet and dry spells.
- Control broadleaf weeds in headlands and buffers using a selective herbicide.
- Minimise traffic on headlands and buffers, particularly when it is wet.

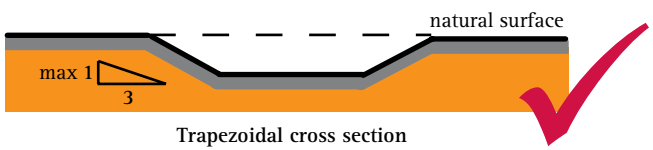


'V' cross section

3.2 Cut-off drains and diversion banks

Cut-off drains and diversion banks are designed to safely intercept water and divert it away from its natural drainage course to protect cultivated or hard bare areas below. They cut across the slope, intercepting runoff from roads for example, and should discharge into grassed waterways or vegetated buffer strips.

The design and dimensions of cut-off drains or diversion banks will vary from site to site and will generally require surveying. They need to be built on a grade which will ensure water flows in the required direction, but not so fast that it erodes the structure, or so slow that allows sediment to accumulate. They also need to be constructed so that they can cope with the volume of water that would be generated by a 1-in-10 year storm event or greater, depending on the sensitivity of the site below.



Trapezoidal cross section

The preferred method of design for cut-off drains, table drains and grassed waterways is pictured above.

Source: ARRB Transport Ltd, 'Unsealed roads manual: Guidelines to good practice', 2000.

Cut-off drains

- Narrow un-grassed cut-off drains with steep side slopes can be subject to erosion. V-shaped or box (U-shaped) drains concentrate water flow, increasing its depth and ability to cause erosion.
- Build cut-off drains with an excavator and trenching bucket with side slopes (batters) that are stable for the soil type and allow easy maintenance - preferably no steeper than 3 (horizontal) : 1 (vertical). Make them wide with a flat floor and established a good grass cover on the batters and floor.
- Direct drainage from a cut-off drain to a stable discharge area such as a vegetated waterway.

Diversion banks

- A cut and fill or all-fill diversion or graded bank, sown to grass, is an alternative to grass headlands on slopes ranging from 10-30%. Banks should be located more frequently across steeper slopes at a frequency that ensures runoff water between one bank and the next does not develop an erodable velocity.
- Diversion banks can cause some inconvenience when working a paddock but can be made so that they are fully trafficable. The best shapes, for minimum interference, can be constructed using a power grader.
- Direct water from a diversion bank to a stable discharge area such as a vegetated waterway.

Farmers on...

Erosion management

In 2007 Ray Daniels from Sunray Strawberries wanted to improve his production drainage systems. Post excavation the drains were showing early signs of erosion and Ray wanted to stabilise the banks and slow the runoff coming into it from the adjacent field. So he planted rows of vetiver grass on the banks and in the drain floor 18 months ago with great success. 'Initially the plants were slow to establish until spring but they quickly grew to 1.6 m after 8 months.' Vetiver grass also has a strong sediment trapping ability and, as on the Daniels' farm, can establish very quickly if the environmental conditions are right.

Farmers on...

Inter-row cover crops

Luigi Coco incorporates white clover and rye grass as an inter-row cover crop to protect his top soil from erosion. Luigi prefers this combination over woodchips because 'it is far too expensive now days'.

Luigi is impressed with 'how it handles big storms like we've had this year'. However he is very keen to find another inter-row cover crop that handles the picker traffic better than the clover/rye mix.

3.3 Vegetation cover between rows

The establishment of grass between strawberry rows is an effective way of minimising soil movement between rows. The root system holds the soil while the top growth protects the soil surface from water droplets. It also slows and filters sediment from incoming rainfall or irrigation runoff, improves trafficability, offers a cleaner environment for workers and promotes cleaner fruit by minimising soil splash.

- Establish vegetation between strawberry rows and manage it to maximise root establishment and leaf density.
- Some growers sow Jap millet (summer) or feed oats (late summer/early autumn) between the rows and herbicide it off before planting. The resultant mulch stabilises the soil between the rows. Other stabilisation options between rows include the use of sawdust or straw.
- If vegetating is not an option across an entire strawberry farm, give attention to grassing critical areas such as rows located closest to dams and watercourses, in conjunction with other drainage management strategies

Table 2 lists species suitable for growing in strawberry inter-rows.

Table 2 – Inter-row plant species list for the strawberry industry in south east Queensland.

Variety - common name	Species	Comments
Brunswick, blue eve or blue dawn	*Paspalum nicorae*	Suitable for sandy soils, red sandy loams, and light clay soils, can handle flooding and frosts. Growth habit- tufted, rhizomatous, and has good weed reduction potential.
Pangola	*Digitaria eriantha*	A low-growing grass that spreads rapidly from rooting runners to form a dense and competitive sward. Pangola tolerates wet and salty conditions and infertile soils. It is hard-wearing. No viable seed, it must be sown from runners.
Dawson pertusa, Indian couch	*Bothriochloa pertusa*	Low-growing, slow-growing. Would need to be grown in a mix of other grasses and legumes to provide enough ground cover. Grow from seed.
Blue couch	*Digitaria didactyla*	Low-growing grass suitable to sandy soils. Slow-growing, so would need to be grown in a mix to provide adequate cover.
Annual ryegrass	*Lolium rigidum*	Recommended varieties- Tama, Midmar, Concord, Aristocrat, Noble, Eclipse. Plant at 30-50 kg/ha. Keep the ground wet for the next 10 days.
Clover (red, white)	*Trifolium pratense* (red), *T. repens* (white)	Legume. Can be included in rye and couch grass planting mix. White clover varieties are Haifa and Ladino.
Lotononis	*Lotononis bainesii*	Legume, low-growing. Slow to establish. Quickest establishment in January/February. Use in a mix with other grasses and legumes. Inoculant group L. Grows well with Pangola if kept short.
Serradella	*Ornithopus spp*	April to May. Seeding 5-8 kg/ha winter-growing annual pasture legume. Madeira and Santorini varieties recommended for southern Queensland. Pods need group G inoculation.

There are multiple benefits associated with grassing between rows. Note the sedimentation at the ends of the inter-rows in the photo on the right.

3.4 Grassed waterways

Grassed waterways (drainage lines), either built or naturally-occurring, carry runoff from higher land, cut-off drains, diversion banks or other structures into farm dams or watercourses. They can also be used to safely conduct water through a cultivated area if diversion of water around a paddock is impractical. Grassed waterways should be wide and shallow with a level floor. This form allows water to spread out and is easy to maintain. It is preferable to construct these waterways with a power or road grader 12 months in advance of use to allow the grassed floor to properly establish. Alternatively, erosion control matting can be used to protect establishing grasses.

- Where appropriate, establish wide, shallow grassed waterways to safely carry water to dams or watercourses.
- Do not use grassed waterways as regular vehicle tracks as developing wheel ruts will become erosion prone. Preferably these waterways should be managed as controlled-traffic areas.
- Maximise grass density in waterways by mowing. Control broadleaf weeds using a selective herbicide. It is recommended that grass height be maintained at 20 cm.
- Grasses that can survive flooding and are suitable for waterlogging soils are Floren bluegrass, bambatsi and Pangola grass.

Farmers on...

Controlled traffic

Luigi Coco uses 4-row beds as a standard. The large amount of plastic combined with the inter-rows requires good filter strips to slow the overland flows during heavy rains.

Luigi employs grassed waterways to handle and direct all the water during large events, 'If I don't use them, every time it rains I'm going to lose my paddocks, I can't afford that with the price of topsoil.'

Grassed waterway diversion drain managed as a controlled-traffic area.

3.5 Sediment traps

Sediment traps or ponds temporarily detain runoff water long enough to reduce its velocity which allows larger eroded soil particles and attached nutrients to settle to the bottom. Sediment traps should be used in conjunction with the other strategies mentioned. They will not prevent soil and nutrient loss by themselves. Much of the good part of the soil (e.g. clay and silt fraction) is lost from sediment traps that overflow; only the 'skeleton' of the soil (large soil particles) are trapped.

A well designed sediment trap will capture all overland flow and allow the sediment to settle out and be retained for future use.

Farmers on...

Sediment traps

Rick, Jeff and David Twist from Twist Berries use sediment traps on their farm to catch any topsoil that does erode during heavy rain.

'We can't afford to lose our top soil – it costs too much to replace – so we use a series of traps to make sure we catch it all during heavy rains.'

'We empty the traps out every year at the end of the growing season and spread the sediment back out over the plots.'

- Design traps to suit the soil type, catchment area to be treated and the equipment available for regular cleaning.
- Runoff leaving a sediment trap should flow along stable non-erodable pathways such as a grassed waterway.
- Sediment traps strategically sited within a well-planned erosion control system that uses other soil conservation measures are better than a large single trap acting as a last line of defence at the bottom of the property.
- Earthen traps are the preferred trapping option. Mesh fencing and hay bales placed across a grassed waterway will only have a temporary effect.

4. Farm tracks

The compacted and exposed nature of farm tracks make these tracks vulnerable to erosion and if not well designed, constructed and maintained, can be a significant source of sediment and nutrients discharged to dams and watercourses.

Track siting and design

- Build tracks on the most stable and hardest ground avoiding areas that will require cut and fill, drainage lines and wet or boggy ground. Ideally, they should be located on ridge tops or on areas with little slope and be wide enough to accommodate both vehicles and table drains.

Pavement

- Tracks should be gently crowned or sloped to shed water and minimise the time and distance water travels down them. They should also be supported by trackside or table drains to carry track runoff.
- Tracks that run down or diagonally across a slope, runoffs or low earthen diversion banks can be constructed which direct runoff from the track. On steep grades, place earthen banks 20-30 cm apart and build them on an angle across the track to avoid water ponding, or concentrating and eroding trackside drains.
- Discharge diversion banks or runoffs into non-erodable table drains or vegetated areas, away from dams or watercourses.
- Where possible, establish grass on low use tracks. Hard-wearing grasses suitable for tracks include blue couch, kikuyu, carpet grass, and Pangola. On high use tracks, crushed rock or surface gravel should be used, even if only in difficult sections.

A low use track sown to perennial grass and slashed regularly.

- Restrict major traffic to designated hard-wearing tracks, particularly in wet weather.
- Wheel ruts concentrate water flow and start erosion. Change wheel tracks to prevent ruts forming. If ruts do form, prevent erosion by using a shovel to build mini-blocks within the rut.
- Avoid tracks through drainage areas or creeks. It is better to build a bridge or culvert that allows traffic to avoid these wet, sloppy areas. Alternatively, stabilise tracks through creeks and drainage areas with concrete, rocks or gravel.
- If planting trees next to tracks, be mindful of shade. Winter shading of laneways reduces the drying action of sun and wind.

Farm drains and tracks are an important part of farm infrastructure. They should be a permanent feature; designed, constructed and maintained in a way that makes them an asset to the farm.

Table drains

- Like cut-off drains, table drains should be wide with a flat floor and batter slopes no steeper than 3 (horizontal) :1 (vertical).
- Ideally they should be made stable with the use of grasses such as couch, kikuyu, Floren bluegrass, bambatsi, and Pangola that can tolerate periods of waterlogging. Drains that carry water for prolonged periods may require rock stabilisation. Aquatic native plants such as Lomandra species or native reeds, which have the added advantage of taking up nutrients, may also be suitable (local NRM & catchment groups, DPI&F and DNRW may be able to provide further advice). Alternatively, vetiver grass is hardy, tolerant of wet conditions, is a very effective nutrient absorber and provides sustained stability to drain floors and slopes.
- Table drains should discharge into stable grassed areas or sediment traps before entering dams or watercourses.

Culverts or pipes

- Culverts must be large enough to handle peak flows. They should be spaced at an interval that will prevent water building up to levels that generate erosion (the steeper the track, the more culverts will be required). Culverts should also discharge into dense vegetated areas or sediment traps, well away from streams, to reduce the velocity of runoff, encourage infiltration and trap sediment.
- Sumps or box inlet structures can be used at the entry of culverts to prevent erosion around the culvert and reduce blockages from sediment build-up.

Construction and maintenance

- Conduct track construction and maintenance when soils are moist – not too wet (boggy) or dry (when soils will not compact). Introduce traffic after a sufficient time for compaction and settling.
- Track maintenance should focus on keeping the road crown or slope and drains effective, avoiding V-shaped or U-shaped clearing of table drains and damage to discharge areas. Indicators for maintenance include eroding batters or track surface, wheel ruts, boggy patches and blocked culverts.

Two examples of drains that require planned actions. The drain above has dimensions compatible with those suggested in this section and only requires the addition of permanent grass cover.

The drain on the left requires an action plan that may involve the reconstruction of the drain dimensions or, at a minimum, a plan that incorporates erosion matting and a mixture of grass seed.

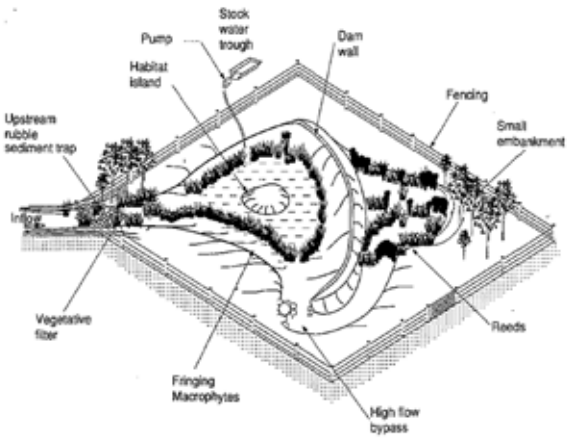
5. Managing dams, wetlands and stream frontages

A vegetated buffer strip consisting of dense perennial grass or native grasses, shrubs and trees slows down runoff and reduces the erosion potential of water entering the adjoining water course or stream. It will also filter sediment and attached nutrients from runoff resulting in cleaner water. This reduces the potential for algal blooms and by reducing sediment build up in dams, means they do not need to be cleaned as often.

In the case of streams, native vegetation offers additional advantages over perennial grass as a buffer. A wider buffer of grasses, shrubs and trees provides habitat for wildlife, beneficial insects, excellent wind protection and spray drift control and stream bank erosion control. Native species from your local area will also establish quickly.

Revegetation stabilises stream banks, filters runoff sediment, attracts wildlife and reduces spray drift.

- Establish perennial grasses in drainage lines that feed farm dams. Avoid spreading fertiliser in these areas unless for maintenance purposes (ensure fertiliser is spread at least four days prior to rain).
- Establish grasses with fibrous roots on dam walls. Do not plant deep-rooted shrubs or trees on these areas.
- Leave a vegetated strip between cultivated areas and streams (refer to Table 3 for recommended widths for different slopes).



Typical design features of a farm dam wetland.

- Consider the use of vegetation that is native to your area as an alternative to perennial grass for streamside plantings. Lists of appropriate species are available from your local council, DNRW or local catchment care group. It is also worth asking about grants that may be available.
- If weed control is required along streams, only chemicals that are registered for use near waterways should be used.

5.1 Natural buffering of runoff

Retaining naturally waterlogged low-lying areas like sedgelands, wetlands and vegetated riparian (streambank) zones on the farm property can provide many long-term benefits. These naturally-occurring zones can trap, remove or treat a range of pollutants, including organic particles, suspended solids (SS), nutrients, pathogens, heavy metals and other toxic particles. Similarly, farm dams or production ponds can be designed

Table 3 – Suggested widths for grassed filter strips in south-east Queensland.

Intensity[1]	Soil erodibility[2]	Slope[3]	Soil loss if poor cover[4] (t/ha/yr)	Suggested filter width (m)	Soil loss if good cover[4] (t/ha/yr)	Suggested filter width (m)
medium (800-1300 mm annual rainfall)	medium (loamy clay topsoil)	low	8	2	1	2
		medium	20	13	1	2
		high	37	24	2	2
high – (1300-2000 mm annual rainfall)	low (heavy clay topsoil)	low	8	2	1	2
		medium	20	13	1	2
		high	37	24	2	2
	medium (loamy clay topsoil)	low	17	7	1	2
		medium	41	26	2	2
		high	74	>30	4	2
	high (silty topsoil)	low	25	15	1	5
		medium	61	>30	3	5
		high	112	>30	6	5

[1] Intensity is how much rain falls and the energy with which it falls.

[2] Soil erodibility is the potential a soil has to erode.

[3] Slope: low = 1-3%; medium = 4-7%; high = 8% and greater

[4] Cover: poor = less than 30% groundcover; good = more than 80% groundcover

Source: Karssies K, Prosser I.P (1999) Guidelines for Riparian Filter Strips for Queensland Irrigators.

as constructed wetlands to achieve multiple objectives, such as:

- improved irrigation and/or stock water quality
- reduced erosion within the dam and downstream
- trapping nitrogen attached to sediments in surface water runoff
- creating habitat
- providing visual amenity.

Farm planning should give consideration to the retention of natural wetlands and terrestrial habitats including watercourses, lagoons and riparian vegetation. Identification and management of these preferential flow paths should be incorporated as part of a sustainable drainage management scheme. Growers should consider the retention of self-sustaining corridors and pockets of vegetation along rivers, creeks and gullies to help maintain native animals and plants. If constructing a farm dam or production pond there should be provision in the plan for revegetation of the area using a mix of trees, shrubs, grasses and sedges to provide different nutrient and sediment-trapping capabilities.

Determining filter widths using Table 3

Scenario A – Block A receives an average rainfall of 1500 mm (high erosivity). The soil type for Block A is a sandy loam (medium erodibility), a 3% slope (low) and has poor ground cover (less than 30%). The recommended width for the filter strip to slow runoff and trap sediment at the lowest point of the block would be 7 m.

If the soil cover of the block were good (more than 80%) the recommended filter strip width would be just 2 m wide.

Achieving soil cover more than 80% requires inter-row ground cover and traffic areas kept grassed at all times.

Scenario B – Block B also receives 1500 mm annual rainfall (high erosivity). The soil is a red brown earth (high erodibility), on a 2% slope (low) and has poor soil cover (less than 30%). A 15 m wide filter strip is required to receive the runoff and allow the sediment to deposit.

With good soil cover (more than 80%) a 5 m wide filter strip would be adequate.

Scenario C – Block C receives 900 mm annual rainfall (medium erosivity). The soil type is a fine sandy clay loam (medium erodibility), on a 4% slope (medium) with good soil cover. A 2 m filter strip is required to slow the runoff and allow the sediment to deposit.

If the same block had poor soil coverage it would require a 13 m wide filter strip.

6. Whole farm planning

Whole farm planning commences with mapping the natural resource features of the property (soil type, slope, drainage, salinity and vegetation) onto an aerial photo. This allows the farm manager to prioritise and make best use of these features when setting up a property, and to decide on those areas that are suitable or unsuitable for cropping.

On established properties, an aerial representation of the farm can help identify and map drainage, salinity, erosion and vegetation issues and existing or proposed improvements to help refine the farm management plan.

See Table 4 for agencies that can provide the tools and assistance to develop a farm plan.

6.1 Farm assessment

Water

- With a farm map or aerial photo in hand, walk around the property – a wet day, when runoff is occurring, is best.
- Mark where water is coming from (roads, paddocks, buildings and parking areas).
- Mark where water is going and how it is getting there (into creeks via erodable or non-erodable pathways such as earthen drains or grassed buffers).
- Note where water runoff is likely to be a short-term issue (for example areas to be worked) or long-term issue (for example farm drains).

Table 4 – Organisations with staff to assist with the development of farm plans (current list as of November, 2008).

Organisation	Plan name	Contact
ALMS	Australian Landcare Management System	(07) 46664112 www.alms.org.au
Growcom	Growcom Farm Management System (FMS)	(07) 3620 3844 www.growcom.com.au
SEQ Catchments	LandPlus (Property Management Planning)	(07) 32114404 www.seqcatchments.com.au

- Check if the rate of water production is greater than the capacity of drains, pipes, diversion banks or grassed waterways.
- Look at the quality and impacts of runoff water. Is it cloudy or turbid? Is there a difference in the quality of water entering and leaving the farm? Has it resulted in deposition of sediment in the dam? Is it causing erosion of farm tracks?

Land

The critical information you need to guide your land management decision is an understanding of the soil types and slopes on your farm. Contour maps are widely available from most Councils and from the service providers identified in Table 4.

The Department of Natural Resources and Water (DNRW) has soil survey maps that cover a range of strawberry growing areas. Frequently this information is not at a scale suitable for detailed farm planning. If you have not got this information, include the following steps:

- With a map of your farm in hand take a walk around your farm and mark the boundaries of the different soil types. For each area make some notes to describe the soil.
- Mark where there are key changes in slope and estimate the slope % for each.
- Assess the suitability of each different area for production, using Table 5 as a guide.

Remnant vegetation and wetlands

Remnant natural areas and wetlands are important to our local wildlife and water quality. While there are regulatory guidelines which farmers are required to meet when considering development and or management of these areas, there are also good reasons to maintain them as part of a production system. Natural areas provide habitat for beneficial predator insects to assist

Table 5 – Land suitability for strawberry production according to soil and slope.

Soil class	Example soil types	Maximum slope for cultivation
Very stable soils	red krasnozems	up to 12% slope
Stable soils	sandy loams with reasonable drainage	up to 8% slope
Unstable soils	fine sands and silty soils, soils based on mudstone, with sodic, poorly drained subsoils	up to 5% slope
Very unstable soils	Loose sands over sodic or impermeable clay subsoil	up to 3% slope. Generally these soils are not suitable for strawberry production due to high waterlogging potential and reduced runoff associated with this soil type/slope.

(Source: These guidelines have been developed by the Department of Natural Resources and Water, contact DNRW Nambour.)

with Integrated Pest Management; they can also provide an ideal location to mount fruit fly traps and can act as windbreaks.

- Obtain a copy of the Regional Ecosystems map for your local area (available on line www.epa.qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/ introduction_and_status/regional_ecosystem_maps) and mark any remnant vegetation on your property plan.
- Obtain a copy of the EPA Wetland Map for your local area (available on line www.epa.qld.gov.au/wetlandinfo/site/MappingFandD/WetlandMapsAndData) and mark any mapped wetlands on or near your property on your property plan. Even if wetlands are not on your property, you may need to consider buffer distances in your farm plan.

6.2 Action planning

Develop a work plan of actions that will:

- achieve 'safe' delivery of water equals slow delivery of water over stable, non-eroding drainage ways
  a) minimise soil and nutrient loss and water runoff
  b) 'safely' transport unavoidable runoff to drainage lines, dams or watercourses
  c) filter any sediment and nutrients from runoff
- include options like shorter row lengths, cut-off drains, diversion banks, grass buffers, grassed waterways and sediment traps
- match production areas to soil and slope suitability (Table 5)
- protect remnant vegetation and wetlands (or seek approvals to disturb these areas).

Integrate the action plan into your business plan and forward budgeting. Investigate options such as grants and incentives available for specific aspects of the plan. The agencies listed in Table 4 can assist the landholder in identifying and applying for grants and incentives schemes that are applicable.

Whole farm planning

There are organisations that have accredited staff to assist and guide farmers through the development of a farm plan (see Table 4). These agencies can provide access to all materials (aerial photography, web support tools etc.) required to develop a farm plan.

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Strawberry growers across south-east Queensland are implementing farming practices to:

- better apply nutrients
- maximise the crop's nutrient uptake
- make best use of rainfall and irrigation
- cover and protect the soil from erosion
- reduce runoff
- improve the quality of runoff leaving their farms

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