Arable guidelines for Managing critical source areas

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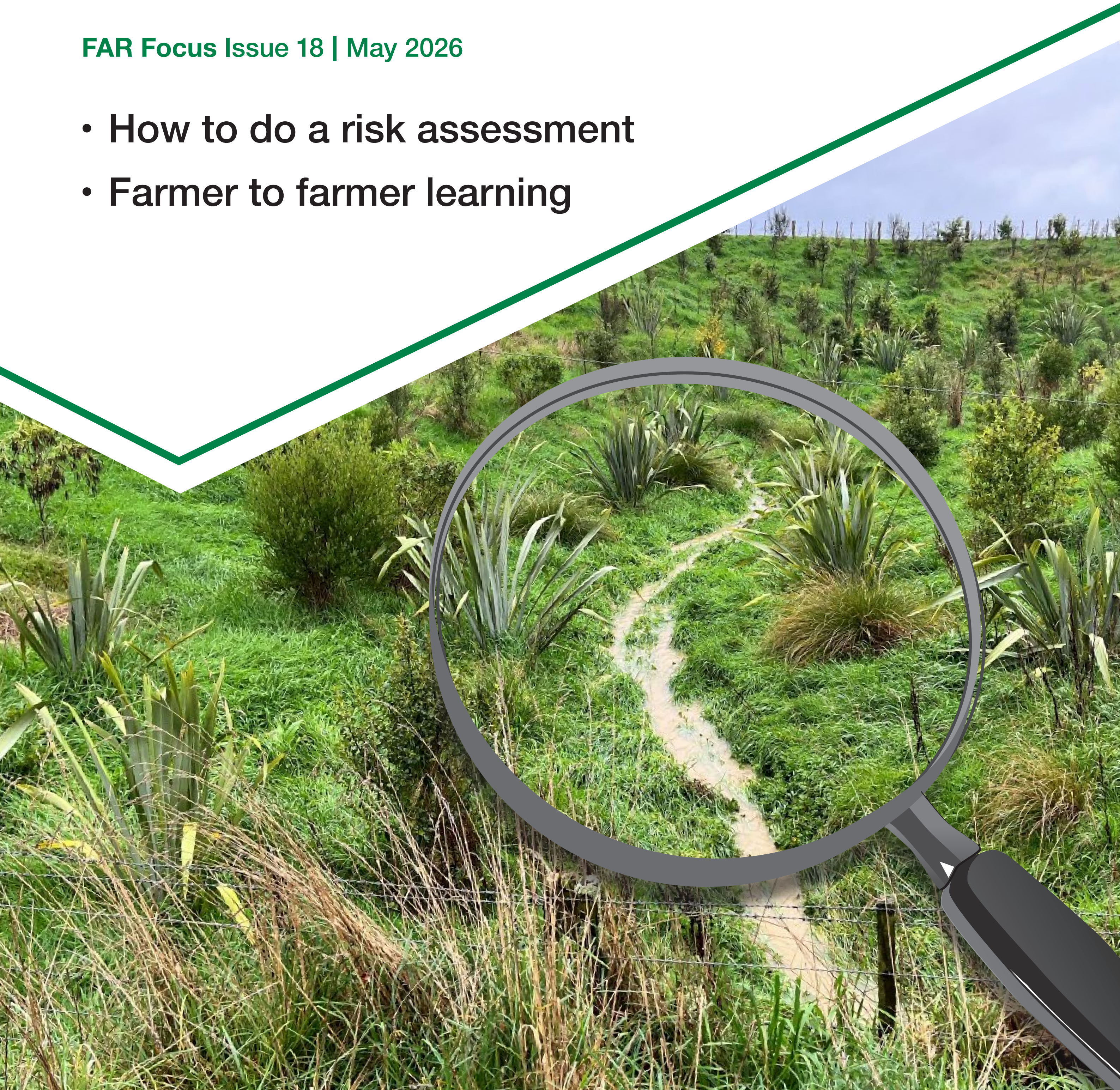
- How to do a risk assessment
- Farmer to farmer learning



Arable guidelines for
Managing critical source areas

Contents

1. Introduction

Aim of the guide

"I believe that these approaches have a huge benefit on the overall sustainability of the farm business. Clients and consumers are becoming much more aware of the environmental footprint of agriculture." - Daniel Finlayson (maize grower and livestock farmer, Waikato).

Careful on farm management is essential to minimise the loss of one of a farm's most valuable assets, its soil.

Critical source areas (CSAs) on arable farms are specific locations where sediment and nutrients are at risk of being transported off paddocks to watercourses and other water bodies. Watercourses include artificial and modified drains, ditches, streams and rivers, which can transport sediment and nutrients to downstream water bodies such as wetlands, lagoons, lakes, reservoirs and estuaries. An extensive list of arable CSA examples can be found in Table 3 in the Appendix.

Effectively managing runoff and CSAs on arable farms requires site specific actions (Table 3) and the flexibility to address challenges unique to arable systems.

Farm environmental planning provides an opportunity for farmers and growers to tell their farm's story, identify and document environmental risks, and explain the reasoning behind management decisions.

This guide was supported by the Ministry for Primary Industries through the Integrated Farm Planning Accelerator Fund. It aims to help farmers carry out CSA risk assessments and identify actions that align with the specific risks on their farms.

The guide explains the four steps to doing a risk assessment:

1. List all CSAs on your farm and consider the level of risk for each.
2. Assign mitigation actions with realistic timeframes to each risk.
3. Keep good records.
4. Learn as you go and modify if needed.

Real life examples demonstrate how mitigation actions have been implemented across different arable farms. The actions highlighted in bold text throughout the guide are linked to specific arable farm risks which are listed in Table 3 in the Appendix. Links to further resources are also provided.

An important objective of this guide is to facilitate farmer-to-farmer learning. Every farmer who has contributed has developed their own approach to managing CSAs. They share a common motivation to implement solutions that make sense for their farms, not simply because they are required to, but because they recognise the long term benefits for productivity, resilience, and the environment.

2. How to do a risk assessment

How to do a risk assessment

“The first part is identifying what the problem is and then asking how can I solve this problem? Farm your way into it and learn as you go. You don’t need to be an engineer, but you do need to take time to work out what the best solutions are, and to talk to the right people.” - Peter Mitchell (mixed arable farmer, North Otago).

The four steps to doing a risk assessment are:

1. List all critical source areas (CSAs) on your farm and consider the level of risk for each.
2. Assign mitigation actions with realistic timeframes to each risk.
3. Keep good records.
4. Learn as you go and modify if needed.

Step 1.

List all CSAs on your farm and consider the level of risk for each.

Identify and list the CSAs on your farm (using Table 3, the examples in this guide, and your own knowledge of your property), then consider the level of risk associated with each CSA. The greater the risk, the higher the priority for mitigation actions. This is an important step in environmental farm planning.

There are no hard and fast rules for assessing risk. Soil texture and slope both play an important role in how water moves across a paddock. Slower draining soils are more likely to generate runoff than free-draining soils. This can be due to compaction or soil type; for example, heavier clay soils tend to drain slowly and can remain wet for longer periods. Steeper slopes also increase risk, as faster moving water will have greater erosive force. It may help to consider where water leaving your farm is heading. Taking a catchment view can provide context for the “why”, it’s not only about keeping nutrients and soil on farm, but also about looking after the environment downstream. All receiving environments, especially sensitive water bodies like the Wainono Lagoon or Lake Ellesmere Te Waihora, benefit from careful management along the way.

Where risk is higher, such as where a CSA sits on a steeper slope and water infiltration into the soil is limited, a larger area may need to be managed. Where risk is more moderate, focusing on the lower part of the CSA may be sufficient. In lower-risk situations, such as wider, gently sloping areas, attention may only be needed around the area where overland flow connects with a waterway. Even on farms that appear flat, small changes in elevation and soil conditions can concentrate water and create a CSA. Water can build momentum over longer distances or be slowed by poorly draining soils, so it’s worth observing and recording how water behaves during wet periods (Step 3).

Step 2.

Assign mitigation actions with realistic timeframes to each risk.

“I learn and join the dots as I go. There are lots of different opinions, once I got it in bite size pieces, and understood my options, I worked with that and then I started to see the bigger picture.” - Tim Gorton (mixed arable farm, Manawatu).

Consider what you know about your farm, along with the ideas in this guide, to help work out what practical changes will make the most difference in each situation. There’s rarely just one right answer, it’s about matching the right action to the problem and learning as you go.

Most mitigation actions fit within one of the following three practical approaches:

1. Keeping soil where it is
Implementing in-paddock good management practices that help keep soil in the paddock is the starting point for managing sediment loss.

2. Slowing or managing water movement
Think about where water is entering, concentrating, or moving quickly, and how that flow can be slowed or redirected.

3. Reducing what leaves the farm system
Where water does move, aim to reduce sediment and nutrient losses before it reaches watercourses.

You’ll find examples of actions to consider for different risks in Table 3 in the Appendix. Elsewhere in the booklet are case studies of how these ideas have been put into practice in different arable farming systems.

Step 3.

Keep good records.

Keeping good records is a key part of the planning process. Record what mitigations are already in place and what is being trialled or planned. This helps track progress over time and builds a clearer picture of how management is evolving year by year as part of environmental farm planning.

Regular checks during or after heavy rainfall can help identify if **grassed setbacks** and **vegetated buffer zones** are working effectively or if **channelised flow pathways** require management (Section 3b).

Make a note or mark on a map (see below for information about Google My Maps) and take photos (Figure 1). It can be helpful to take photos of:

- Where water is coming from.
- Where water is going.
- Where water should go.
- How existing actions are performing (before and after images are very useful in farm environment planning).

Figure 1. Take photos on your farm of how water behaves during and after heavy rain.

Technology can help with record keeping and decision making

Google My Maps can be used to draw on maps and pin notes and photos.

- In Google My Maps, click on 'create a new map' and locate your farm.
- Use the draw tool to outline CSAs or paddocks.
- Add pins to mark key features (e.g. drains, entry points to waterways).
- Include notes (e.g. "ponding after heavy rain") or photos.
- Draw lines to show how water flows across paddocks.
- Share the map with others involved in your farm plan.

Maps such as Google Maps or Google Earth can be overlaid with high resolution elevation data (e.g. RTK or LiDAR) to better identify areas prone to water ponding and likely flow paths. In some situations, enhanced GNSS positioning services such as SouthPAN can also be used to collect more accurate flow paths in the field. More advanced software can be used to test land contouring scenarios and assess where surface or subsurface drainage may provide the greatest environmental benefit.

As technologies are evolving rapidly, farmers interested in using higher accuracy positioning or elevation data are encouraged to talk with a local GIS provider or contact FAR for guidance on suitable options.

Step 4.

Learn as you go and modify if needed.

> *"Focus on bang for buck and being prepared to modify until it works. Can't lock up and leave so to speak."*
> *- Kennedy Lange (Senior Biodiversity Advisor, ECan).*

Once your mitigations are in place, the key thing is to assess the result. You can always modify your plan if needed. For example, if you have installed and are maintaining grassed setbacks at the edges of a watercourse to intercept runoff water, but you find there is preferential flow, it may be worth widening the setback in this area.

In many cases, farmers may need to trial solutions on farm, especially where there is uncertainty or conflicting advice about how a mitigation will perform in a specific place. Conditions vary from farm to farm, so what works well in one situation may not translate directly to another.

Small-scale on farm trials are a practical way to test whether a perceived problem is as significant as expected, and whether a mitigation is effective in that context. Starting small allows adjustments to be made without committing the whole system upfront.

3. Farmer to farmer learning

Farmer to farmer learning

"Getting started can be the hardest part so starting small, learning from others and seeing for yourself can be the best way to go." - Andrew Darling (mixed arable farm, South Canterbury).

Through farmer-to-farmer learning, growers share what works on their own farms, helping others identify effective, realistic strategies for managing runoff and reducing soil loss.

3a. Exposed watercourse banks and riparian zones

Vegetated buffer zones can significantly reduce soil loss compared with bare soil. FAR's MPI Sustainable Farming Fund: Good Management Practices for Cropping Setbacks project, found sediment reductions of around 37% from 1 metre **grassed setbacks**, increasing to 63% from 5 metre grassed setbacks. Factors such as slope, soil type, and how water moves across the paddock all influence what is appropriate. In practice, it's about picking your places, wider where it counts, and narrower where that's enough. National and regional requirements may apply, as these can set minimum expectations for setback widths.

Riparian planting along waterways plays a critical role in reducing erosion, retaining soil on farm, and maintaining stable bank structures. Waikato maize grower and livestock farmer Daniel Finlayson, who farms along the banks of the Waipā River, is taking a practical and staged approach to riparian management. His philosophy is to act where it makes immediate financial and operational sense, while continuing to work towards longer-term environmental and farm management goals.

A key focus for Daniel has been addressing unproductive and pugged areas, places where stock frequently got stuck and where little to no production value was gained from keeping them in use. For Daniel, fencing these areas off was "a no brainer," providing instant benefits in animal welfare, soil protection, and reduced sediment movement toward the river.

Until he has the budget to complete full native revegetation, the existing grass cover in these fenced off zones is stabilising soil, slowing runoff, and preventing further degradation. This staged approach allows Daniel to balance environmental improvement with financial realities, showing how incremental steps can still achieve meaningful progress while working toward more ambitious goals (Figure 2). Daniel's advice is to start small and plan for the future as it does not all need to be done at once.

The same problem in a different place may require different solutions. For example, on Daniel's farm along the Waipā River, the river channel is deep and floods tend not to undercut established trees. In contrast, at Peter Mitchell's farm in Otago, mature trees along waterways have, at times, exacerbated soil loss. During flood events, fast-flowing water can scour soil from around the base of trees, undercutting the bank, whereas grassed banks are more resilient in these conditions (Figure 3).

Figure 2. Area fenced off and grassed compared to an area that has been planted out.

Figure 3. Areas of the bank with trees show scouring around the tree bases compared with sections of the bank covered only by grass.

Peter plans to allow grass to re-establish along the banks and plant flaxes closer to the paddock edge (Figure 4, left). These will provide shelter for stock while also acting as a flexible, natural barrier ("flax fence"). Installing a conventional fence in this location is unlikely to be effective, as floodwaters would damage or destroy it. For Peter, thinking about the flow of water is important.

"If there is a 200 ml rain event resulting in rapid water flow, we need something the water can flow over, flatten and not scour out."

Peter is trying *Carex* as he has found these plants can handle the flow (Figure 4, right), reduce weeds in the waterway that cause blockages and, on the north side of watercourses, provide shade for the eels. He plants flaxes on the corners of creeks because he has found they have a good root base to help stop floods scouring the banks.

Figure 4. Left: Peter plans to plant flaxes closer to the paddock edge. Right: *Carex* planted along a watercourse.

On his mixed arable farm in the Manawatu, Tim Gorton manages several waterways, including a river boundary and multiple overland flow paths. He has found that leaving grass and planting trees with deep, fibrous root systems binds soil and protects stream banks, reducing sediment loss to waterways (Figure 5).

Figure 5. Riparian plantings in Manawatu.

"Now that I have started on this path, the more I notice new opportunities like unproductive areas or corners."

"Getting all the freebees that you can helps. Horizons offer some useful free services, including information on how much to plant and where, and reminders around management."

One of the practical actions Tim has implemented is fencing-off steep, unproductive areas where water naturally concentrates, transporting sediment downslope (Figure 6). Once fenced, the grass cover in these zones slows runoff, allowing soil to settle before reaching the waterway. Tim has complemented this with native riparian plantings, which further stabilise the soil and provide an added ecological benefit: nectar and habitat for beneficial predators and parasitoids. These natural enemies support biological control of pests within his cropping system (see the next page for more information).

Figure 6. Fenced off area where the grass and biodiversity planting help filter out sediment during periods of high rainfall.

Tim's advice is to figure out what your limits are. "Don't bite off more than you can chew. One year we had 1600 trees to plant and that was too many in one shot. For us, an achievable amount is 400-500 in one hit."

Grass buffer zones can also include plantings which can provide shelter benefits (Figure 7).

Figure 7. Adjacent to a creek in Southland a buffer zone has been left and planted with trees for shelter (Image source: Ballance Agri-Nutrients).

Riparian planting and native biodiversity guides

"I happen to like native plants as they don't attract as many birds that eat our crops, but planting needs to be appropriate for the flow." - Peter Mitchell (mixed arable farmer, North Otago).

How to guides for riparian plantings for you region can be found on the Dairy NZ website (see Appendix for QR code): www.dairynz.co.nz/environment/waterbodies-and-wetlands/riparian-planting

Riparian margins can be divided into three distinct planting zones, each serving a different purpose and requiring specific plant types (Figure 8). A grass strip between the paddock and planted area is important. Reductions in sediment flow are only achieved where vegetation is dense at ground level, so maintaining a strip of grass helps slow water and trap sediment before it reaches the channel. The upper bank zone sits on higher ground but may still flood occasionally. Plant flaxes, grasses, shrubs, or trees that provide shade and shelter to the waterway. This shading helps moderate water temperature and improves habitat conditions. The lower bank zone, if frequently flooded, requires well-rooted, waterlogging-tolerant species. Sedges and rushes are well suited, as they can withstand extended periods under water and help stabilise the bank. Species such as *Carex secta* and *Carex seminata* are effective at trapping sediment and creating structure. Plant densely near the water's edge to provide overhanging habitat for aquatic life and improve bank stability.

Once established, riparian vegetation lowers water temperature, reduces weed and algae growth, and creates a more stable aquatic environment. Without adequate shade, water temperatures can fluctuate widely; many native fish species struggle at temperatures above ~25 °C. Warmer conditions also promote aquatic plant and algae growth, which can clog waterways and reduce dissolved oxygen levels needed by fish and invertebrates.

Figure 8. Three distinct planting zones of riparian margins.

"For us natives are the way to go, once we changed from exotics to natives it has been much more satisfying and rewarding."
- Daniel Finlayson (Maize grower and livestock farmer, Waikato).

Native biodiversity plantings on farm can also enhance underused corners of the farm, provide shelter, reduce erosion, support social licence, and build resilience by encouraging beneficial insects; pollinators, predators, and parasitoids. Many native plants can support a diversity of beneficial insects capable of improving pollination and suppressing pest populations on arable farms. Including plant species with different flowering times in biodiversity plantings can provide continuous nectar for beneficial insects throughout the season. Nectar supports the adult stage of many beneficials and increases their flight capacity, life-span and the range they can search for hosts. For example, parasitic wasps can control far more aphids when they have access to nectar rather than water.

The Bioeconomy Science Institute (formally Plant & Food Research) and MPI Sustainable Food and Fibre Futures programme, Beneficial Biodiversity for Greater Good – Designing native plantings for beneficial insects, has developed practical guidelines to support this. They focus on designing native plantings in Canterbury with a diverse mix of species that flower at different times, providing a continuous food source for beneficial insects. Search 'Selecting native plants that attract beneficial insects: A Canterbury Guide' on the BSI website (see Appendix for QR code).

3b. Channelised flow in vegetated buffer zones

Maintenance of vegetated buffer zones and grassed setbacks is required to ensure they remain effective. Good consistent ground cover is important as scouring or channelised flow will reduce effectiveness. Any channels, bare or damaged areas, including those created by wheel tracks or subtle changes in topography, should be filled and if necessary re-seeded. Re-levelling may be required to address ponding or uneven ground that concentrates runoff. Ideally there should be uniform sheet flow across the buffer to maximise the interception and filtering of sediment, rather than concentrated or channelised flow.

Inspections, particularly during winter and following rainfall events, can help identify how runoff is entering the buffer and whether preferential flow paths are developing. If you find there is preferential flow, it may be worth considering widening the setback in this area.

Sediment deposits that accumulate along buffer edges should also be removed, as they can form unintended bunds that divert water away from the vegetated strip. While sediment build-up may indicate the buffer is effectively trapping contaminants, excessive accumulation can reduce its performance.

3c. Overland and preferential flow paths

The right approach to slowing or managing water movement will depend on your farm system, soils, and where the problem areas are. **Contour and interception drains** can be used to avoid water flowing or pooling where you don't want it. Both contour and interception drains must discharge into a stable, permanent drain, otherwise the problem of erosion is shifted elsewhere.

"Water pooling on the surface results in crops not growing well, and where crops don't grow well, it becomes a source of sediment and weeds." - Andrew Darling (mixed arable farm, South Canterbury).

Figure 9. A vertical sump system is used so the water from a depression can drain to the ditch at the edge of the paddock.

Figure 10. Gentle contours re-directing surface water to a drain.

In North Otago, mixed arable farmer Peter Mitchell has an extensive drainage system in place, using field tiles and vertical sumps as well as open channel **interception drains**. This helps him manage water movement across his paddocks to reduce soil loss. In low lying areas with heavy clay soils, where water tended to accumulate in depressions, a vertical sump system was installed, allowing excess water to drain via Novaflo pipes into a ditch at the edge of the paddock (Figure 9).

Peter has found creating gentle **diversion bunds** to be an effective way to direct surface water to drains or creeks at the edges of paddocks to reduce surface flows and scouring which removes valuable soil from the paddock. These contours are barely visible, highly effective and very affordable (Figure 10).

Once you have intercepted the flow it's important to think about where that water ends up. The same applies if you're using sub-surface drainage, open drains, or a combination of both.

Intensive mixed cropper Tim Gorton's Manawatu farm borders a river and has multiple water pathways.

"A big focus has been reducing surface water with tiles and drains, then managing the CSAs one step at a time."

Ideally, runoff from sub-surface drainage should pass through a vegetated buffer before entering a permanent or intermittent waterway. This helps slow the water down and trap sediment and nutrients (Figure 11).

In North Otago, a preferential flow path created by an irrigator wheel in a typically wet area resulted in the farmer planting the corner in permanent grass to minimise the pathway for soil to get into the watercourse (Figure 12).

A novel approach to managing preferential flow paths was demonstrated by a South Otago farmer who used *Carex* planted in straw bales as a vegetated buffer to trap sediment in a low-lying area where runoff was concentrated through a gap in a macrocarpa hedge. The bale-and-plant barrier intercepted runoff from the upper paddock, capturing sediment before it could move downslope (Figure 13).

Figure 11. Outlets should direct water to a filtration area and not bare soil.

Figure 12. Before (2018) and after (2023) planting out a typically wet area in a difficult corner in North Otago.

Figure 13. A gap in the hedge planted with *Carex* at the low point between two paddocks to stop soil transportation down slope.

3d. High risk overland and preferential flow paths

Where the risk of contaminant loss is high, reducing what leaves the farm may require larger-scale interventions, such as **sediment traps**, to minimise sediment and nutrients reaching waterways.

Sediment traps are designed to slow the flow of water, for example by creating a deeper pool or settling area within a drain or watercourse, allowing sediment to settle out before water flows downstream. Sediment traps are typically shallow, relatively simple to construct, and easy to maintain and clean out.

The University of Canterbury Water Rehabilitation Experiment (CAREX) in partnership with Living Water initiated a sediment trap demonstration (a link to this work can be found in Table 3 in the Appendix). They constructed a sediment trap approximately 12 metres long and 0.9 metres deep (Figure 14). Shallow, elongated sediment traps that fit within the width of a watercourse minimise the loss of productive land while slowing water flow over a greater distance. This increased flow path also improves the capture of finer sediment particles.

A table was developed to provide guidelines for building sediment traps that fit watercourse dimensions and capture approximately 50-60% of the transported load (Table 1). Water velocity can be estimated by throwing a stick and seeing how long it takes to move over a known distance.

Sediment traps need regular cleaning to keep working effectively. How quickly they fill up will depend on how much sediment is moving through the waterway, so clean-out frequency varies from site to site. Experience will soon indicate how often maintenance is required. As a guide, a trap of 12 metres long and 0.9 metres deep can typically be cleaned out in around 20 minutes using a digger.

Figure 14. A 12 metre long and 0.9 metre deep sediment trap dug into a watercourse. The longer and slower the water moves through the pool, the more sediment will settle out (Image source: Canterbury Waterway Rehabilitation Experiment (CAREX)).

Table 1. Suggested sediment trap dimensions based on the width and water velocity of the waterway.

Suggested trap length x depth		Average width (m) <1.5	1.5 - 3.0	3.0 - 4.5
Water velocity (ms^{-1})	<0.2	4.0 x 0.5	7.0 x 0.75	9.0 x 1.0
	0.2 - 0.4	7.0 x 0.5	10.0 x 0.75	12.0 x 1.0
	0.4 - 0.6	10.0 x 0.5	13.0 x 0.75	15.0 x 1.0

Figure 15. Sediment trap at the base of a critical source area (Image source: Ballance Agri-Nutrients).

Sediment traps are most effective when used alongside other practices that reduce the amount of soil entering runoff pathways in the first place, such as **riparian planting** and **vegetated buffers**. They can be installed at the end of a flow path (Figure 15) or staggered across areas prone to soil loss, with multiple interception points helping to improve overall effectiveness. Sediment traps can be used in both ephemeral and permanent watercourses.

Detainment bunds are sediment traps designed to temporarily store farm stormwater runoff behind a ridge of compacted earth, with controlled outlets to manage water levels during storm events. By retaining water for up to three days, detainment bunds maximise the settlement of sediment while generally avoiding adverse impacts on pasture growth. Although research is required to assess crop impacts, drainage requirements, and design adaptations for arable farms, detainment bunds have been shown to fit well with catchment-scale approaches where flows are shared, i.e. larger bunds may be suited for neighbouring pastoral land. Coupling detainment bunds with **constructed wetlands** has been shown to further improve treatment efficiency. Further guidance on detainment bunds can be found in links in Table 3 in the Appendix.

Constructed wetlands need to be designed to fit the catchment, rainfall, soil type and contaminant issue. While they may not be practical everywhere, even small or simple wetland areas can deliver benefits (see the next page for more information). The focus is to recreate habitat at little or no productivity cost. Expert advice can ensure the right design and plantings (Table 2) are chosen for the right situation. On arable farms, where every bit of productive land counts, small off-line sedimentation ponds (Figure 16) or in-line filtration wetlands (Figure 17) are a good option. Off-line constructed wetlands take more space but allow for greater bypass flow during flooding.

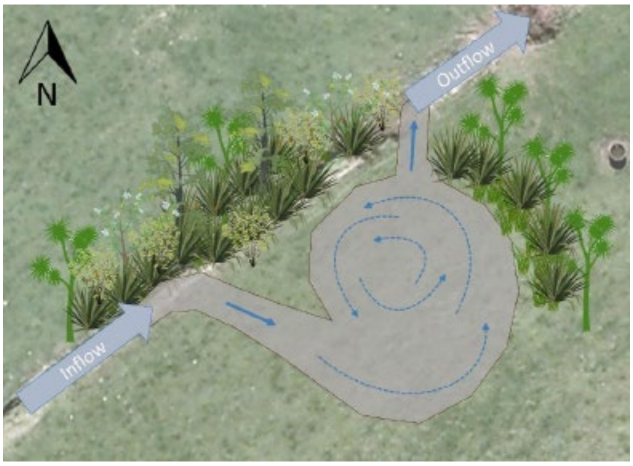


Figure 16. Off-line sedimentation pond design (Image source: Wai Kōkopu Consulting).

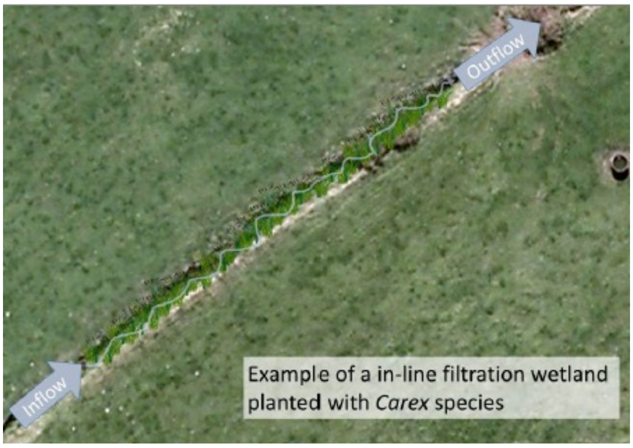


Figure 17. In-line filtration wetlands (Image source: Wai Kōkopu Consulting).

Table 2. Recommended plants for in-line filtration wetlands.

Maori name/ common name	Botanical name	Lifeform	Planting zone
pūrua, marsh clubrush	*Bolboschoenus fluviatilis*	sedge	sedge/rushland
kāpūngāwhā, kuawa	*Schoenoplectus tabernaemontani*	tall rush	sedge/rushland
giant rush, leafless rush	*Juncus pallidus*	rush	sedge/rushland
tussock swamp twig rush	*Machaerina juncea*	rush	sedge/rushland
jointed twig rush	*Machaerina articulata*	rush	sedge/rushland
teasel sedge	*Carex dipsacae* *Carex fascicularis*	sedge sedge	sedge/rushland sedge/rushland
Rautahi, cutty grass	*Carex geminata**	sedge	sedge/rushland
purei, pukio, niggerhead	*Carex secta**	sedge	sedge/rushland
speckled sedge, trip me up	*Carex testacea*	sedge	sedge/rushland
pukio, swamp sedge	*Carex virgata**	sedge	sedge/rushland
tupari-maunga, giant umbrella sedge	*Cyperus ustulatus**	sedge	sedge/rushland
harakeke, flax	*Phormium tenax*	herb	riparian / shade
toetoe, kakaho	*Austroderia toetoe*	large grass	riparian / shade
mānuka	*Leptospermum scoparium*	small tree	riparian / shade
hukihuki, swamp Coprosma	*Coprosma tenuicaulis*	shrub	riparian / shade
tı kōuka, cabbage tree	*Cordyline australis*	tree	riparian / shade

Arable constructed wetland example developed by Wai Kōkopu Consulting

A rolling South Canterbury paddock with multiple flow paths servicing four southern sub catchments of 15-86 ha was used as an example paddock to demonstrate a range of options. Options identified were a constructed treatment wetland (CTW) train, tile drains with a CTW at the end, or an in-line filtration wetland (FIL-WL) (Figure 18).

An off-line constructed treatment wetland opportunity could service the middle area of the paddock (Figure 19).

The in-line filtration wetland scenario (Figure 20) would require increasing the width of the channel by 1-2 metres (Figure 21), however, this would not necessarily result in a gross loss of productivity given that improving the drainage could improve yields in the low production areas that currently exist on either side of the channel.

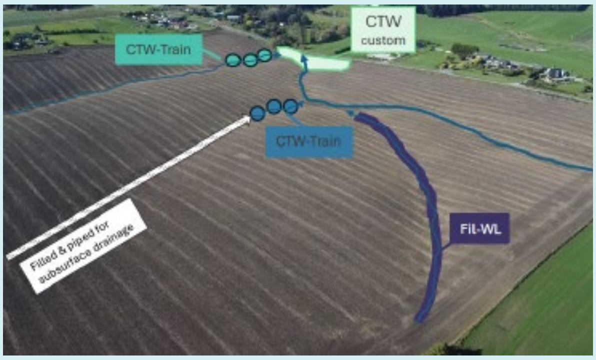


Figure 18. Example placement of a constructed treatment wetland (CTW) train, tile drains with a CTW at the outlet, and an in-line filtration wetland (FIL-WL).

Figure 19. Off-line constructed treatment wetland.

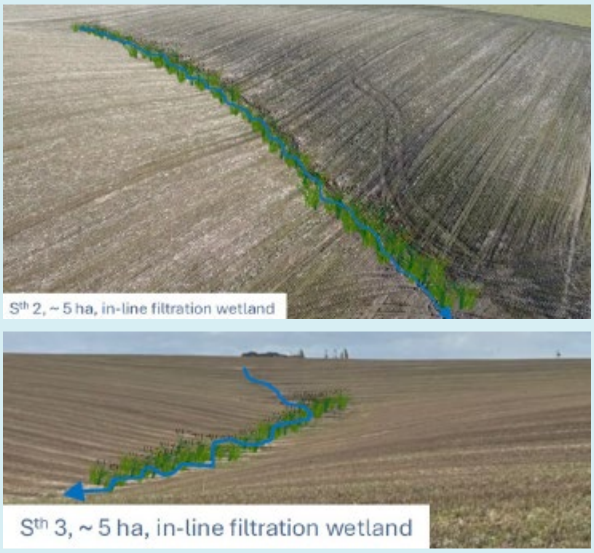


Figure 20. Sub-catchment with in-line infiltration wetland.

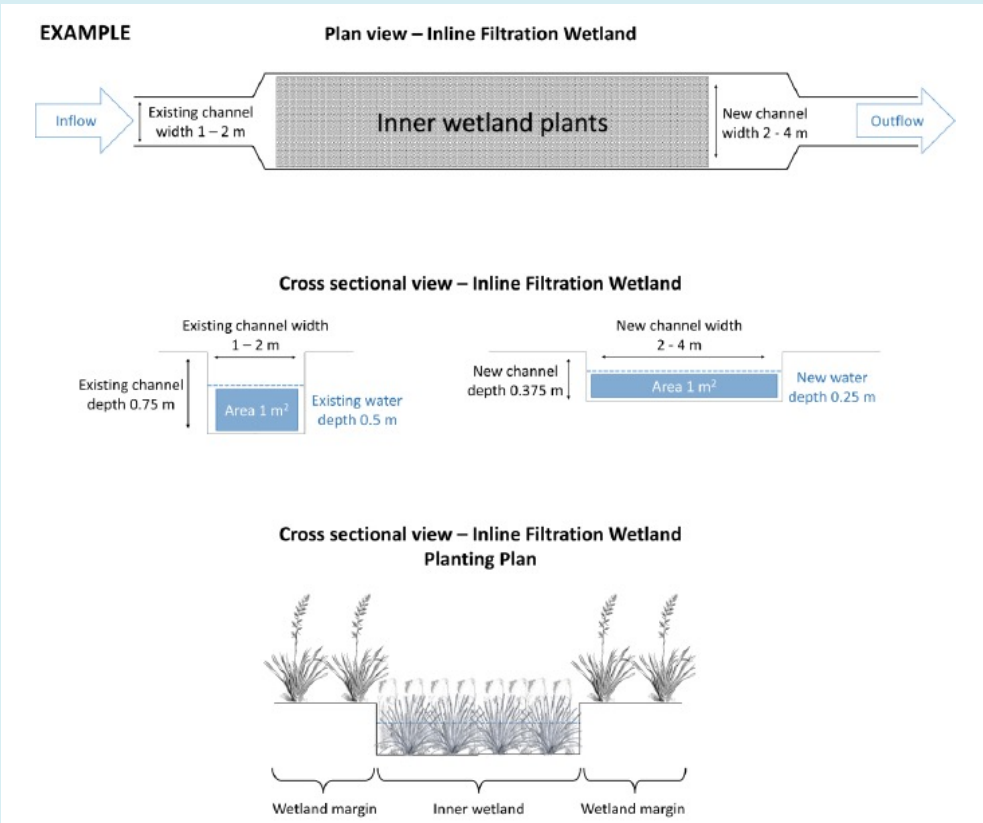


Figure 21. In-line filtration wetland option for the southern sub-catchment scenario.

3e. Swales and ephemeral watercourses

Swales and ephemeral watercourses are natural drainage pathways that can transport sediment to permanent waterways. An ephemeral watercourse is a channel that only flows intermittently, typically after rain, and can be dry for much of the year.

Pay close attention to the receiving end before it reaches the drain or pathway to a waterbody. **Vegetated buffer zones** can be very effective at managing the exit points as the grass area at the receiving end of the ephemeral system slows the water down and allows sediment to settle out (Figure 22).

Figure 22. Permanent grass where there is connectivity between swales and watercourse.

Where appropriate, **permanent planting** could be a good option. Andrew and Amy Darling manage a mixed arable farm that includes low lying ephemeral watercourses, areas that remain dry for much of the year but can flow during winter. Initially, the Darlings were uncertain about how permanent planting in these areas might affect water movement, sediment loss, and crop management. Conflicting advice from experts increased this uncertainty, particularly around which species would perform best, how plantings might interact with herbicide programmes, and whether vegetation would slow or divert flows in ways that could harm crops. Before over committing, they wanted to see for themselves how *Carex* species would behave in their specific environment in a small area.

In early September 2024, they started a trial. Prior to planting *Carex secta* and *Carex geminata*, the ephemeral channel was sprayed out (August 2024) and mechanically reprofiled to create gentler banks to plant into (Figure 23).

Figure 23. Incised erodible banks before and after reprofiling.

The planting design included two rows of *Carex* along 400 metres of waterway, spaced approximately 1.75 metres apart with 1.5–2 metre spacing between plants (Figure 24).

Figure 24. Trial planting of two species of *Carex* in an ephemeral watercourse.

The Darlings consider the trial a success and are encouraged by the *Carex* that have formed a robust physical barrier that can arrest gross load while still allowing for flow.

Being on the town belt on the main highway, the farm is highly visible. Since the planting, Andrew and Amy have had calls from urban neighbours sharing their appreciation. Fostering positive relationships are important and native plantings on farm builds pride that communities notice, and it demonstrates that farming and nature can coexist.

The next step for the Darlings is to see if planting a section without the re-profiling will have the same effect. Although the re-profiling created gentler, more stable slopes to plant, it created a lot of soil that needed to be moved. There are always trade-offs, but seeing for yourself can help with decision making.

Site prep and preplant spray was carried out by the farmer. Planting 450 restoration grade *Carex* seedlings and fertilising was carried out by Brailsfords. Based on 2024 costs, this required a budget of $4450 and an additional $1080 for a season of maintenance.

Intensive winter grazing and CSAs

Intensive winter grazing (IWG) includes grazing livestock (cattle, sheep and other livestock) on an annual forage crop between 1 May and 30 September. An annual forage crop is a crop grazed where it is grown (e.g. fodder beet, kale, swedes) but does not include pasture or arable crops going through to harvest. The national wintering rules require a minimum of a 5 metre buffer around waterways, wetlands or drains (regardless of whether there is any water in it at the time). Buffers around CSAs (i.e. swales, gullies and waterways), need to maintain vegetation cover until after 30 September. Regional rules around IWG may vary and need to be factored in.

While permanent grass cover is often recommended for ephemeral pathways (Figure 25), arable farmers face additional management and agronomic considerations. For example, if coming out of a crop it could be impractical to sow a small area in grass when planting the rest of the paddock in a forage crop. Contamination issues also need to be considered. Understanding what rules apply where you farm is the first step. If contamination is a concern with planting grass, in some regions it may be accetable to put the CSAs into a short rotation crop like oats that would grow quickly, provide a good buffer and be grazed just before the spring crop is sown.

Figure 25. Maintaining grass cover in swales limits soil transport.

"The aim is to minimise soil going into CSAs with in paddock management. Keeping soil in the paddock in the first place is the first step." - Andrew Darling (mixed arable farm, South Canterbury).

Winter grazing plans should demonstrate that paddock-specific risks have been assessed and that management actions are tailored to the characteristics of each paddock, including provisions for adverse weather events. Stock exclusion and buffer widths from CSAs should reflect the level of risk and may need to be wider where preferential flow paths exist (regional council rules will need to be factored in). For example, particular attention may need to be given to the receiving ends of ephemeral flow paths. Additional contaminant interception measures may include the strategic placement of hay bales at the terminal ends of flow paths to capture sediment.

Establishing catch crops or resowing land as soon as practicable after winter grazing is key to taking up surplus N and restoring soil structure. Intensive winter grazing can result in considerable compaction because the high densities of stock grazing a standing crop often coincides with a period of high soil water content. However, compaction remediation with living roots can be fast. Where a compacted winter grazed paddock in Southland was left fallow after a grazing event the soil remained compacted. In the same paddock, where the soil was cultivated after grazing and sown in an oat cover crop, the organic matter from the roots resulted in improved visual soil structure over a time frame of a few months (Figure 26).

Figure 26. Catch crop roots can alleviate soil compaction by penetrating compacted soil layers and creating pore spaces, while root exudates help bind soil particles and improve soil structure.

Even if there is not connectivity to water bodies it makes good sense to keep soil in the paddock. Soil quality is important, poor structural stability for example means that soils are more susceptible to moving. Compaction can lead to surface water pooling, increasing the risk of sediment run-off. Good management practices like reducing soil disturbance, leaving crop residues, and where possible minimising fallow periods in the rotation, all reduce high-risk situations for runoff.

FAR Focus 15 (see Appendix for QR code): Good soil is good business: www.far.org.nz/resources/far-focus-15-good-soil-is-good-business

3f. Impervious areas

Intercepting surface water flowing off hard surfaces like roads and tracks protects paddock soil from scouring. The volume of water coming off these areas can be underestimated, particularly in heavy rainfall. Where runoff from tracks and gateways occurs near permanent or intermittent waterways, these areas can act as CSAs. In these situations, runoff should be actively managed e.g. by manipulating the camber of the track so it is slopes in the opposite direction, with **interception drains** or by filtering it through **vegetated buffer strips**. On a North Otago farm, interception drains are used to divert runoff from the Alps to Ocean bike trail away from cropped paddocks. Prior to this, the sealed surface concentrated water flow into the paddock, causing scouring and poor crop establishment, and creating a weed burden. Installing an interception drain above the paddock redirected this flow, preventing water from entering the cropped area and reducing both soil loss and weed pressure (Figure 27).

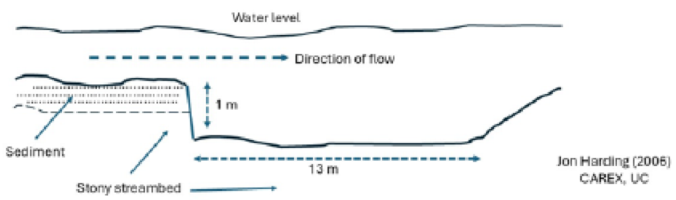
Figure 27. An interception drain catches runoff from a hard surface before it can scour part of the paddock (before and after).

Appendix

Appendix

Table 3. Examples of critical source areas and possible mitigations for arable farms.

Keeping soil where it is	
Risk	**Mitigation actions**
Compaction: Compaction can result in water pooling on the soil surface, increasing the risk of sediment runoff.	**Avoid working wet soils** as they are particularly vulnerable to pugging and compaction from livestock and machinery. **Cover crop** roots (such as from an oat catch crop after winter grazing) can alleviate the effects of soil compaction as roots release sugars and other compounds that help bind soil particles and because the roots themselves penetrate the compacted layer, creating pore space and structure. **Deep-rooted crops** can help improve soil structure and reduce the effects of compaction at depth. For example, tap-rooted species such as lucerne, chicory, sunflower and lupins can penetrate deep soil layers. **Increasing the return of organic matter** to the soil can help improve soil structure and reduce the risk of compaction. Find out more in 'Good Soil is Good Business' (see end of Appendix for QR code). www.far.org.nz/resources/far-focus-15-good-soil-is-good-business
Poor drainage: Poor drainage can result in overland flow when rainfall exceeds the soil's ability to absorb water. This is more likely to occur during winter when soils are wet or saturated. FAR trials have found that soil saturation is a major driver of sediment loss in runoff events.	Where appropriate, **artificial drainage** can improve infiltration and reduce runoff. Using **precision irrigation** can help avoid over-irrigation, reducing the risk of soil saturation and overland flow. **Maintaining good soil structure** and **minimising fallow periods** can improve drainage, increase infiltration, and reduce the risk of sediment loss. Find out more in 'Good Soil is Good Business' (see end of Appendix for QR code). www.far.org.nz/resources/far-focus-15-good-soil-is-good-business
Tillage: Tillage can be a risk where rainfall events induce runoff while soil is exposed, disturbed, and without crop stabilisation.	**Contour cultivation** can reduce soil loss compared with cultivation up and down the slope, with research showing reductions ranging from 30% to more than 90%, depending on site conditions. While **direct drilling** does not suit all farming systems or crops, FAR trials have shown that it improves soil surface stability compared with conventional cultivation, which could reduce soil loss in runoff events. If cultivating near waterways and slopes, find out the local rules for setback requirements from waterways and slope limits for cultivation.
Bare soil: Bare soil can increase the risk of soil loss during rainfall events, as the absence of crop cover and root stabilisation leaves the soil vulnerable to erosion and transport by runoff.	**Retaining stubble** on the soil surface provides ground cover and can reduce soil loss by 50% to 80% compared with bare soil, depending on the site and amount of residue. **Replace fallow with cover crops where practical**. Cover crops protect the soil from raindrop impact and sheet, rill, and wind erosion, while helping to recycle nutrients remaining from the previous crop. FAR trials have found that even short-term cover crops can improve soil stability and return organic matter to the soil through root activity and above-ground biomass.
Declining soil organic matter: Declining soil organic matter can increase the risk of soil loss because organic matter helps bind soil particles into stable aggregates, improving soil structure and reducing susceptibility to runoff and erosion.	**Include restorative phases** within the crop rotation to maintain or build soil organic matter. These phases are characterised by lower levels of soil disturbance and crops that produce high root biomass, increasing below-ground organic matter inputs. For example, on mixed cropping farms, pasture is often the key restorative phase. In intensive arable systems, ryegrass seed crops can serve a similar role, particularly when allowed to regrow so they remain in the rotation longer.

Slowing or managing water movement	
Risk	**Actions**
Exposed watercourse banks and riparian zones (Section 3a): Exposed banks and riparian zones (strips of land beside watercourses and water bodies) allow easy movement of sediment, nutrients, and contaminants to enter waterways.	A **vegetated buffer zone** is a vegetated strip of land, typically grass, established between a farming activity and a sensitive feature such as a watercourse. Vegetated buffers can be used to stabilise banks, slow runoff, trap sediment, and increase water infiltration before it reaches waterways. A grassed **setback** is an example of a vegetated buffer zone. Grass strips between paddocks and watercourses work because sediment flow velocities are generally reduced by vegetation that is uniformly dense at ground level. FAR research found sediment reductions of 37% with 1 metre setbacks and 63% with 5 metre setbacks, indicating that wider setbacks may be needed in higher-risk areas, such as where setbacks intercept preferential flow paths. Variable rate buffer strip information can be found (see end of Appendix for QR code): www.landscapedna.org/actions/interception/variable-width-buffer-strips/ How to guides for riparian plantings for your region can be found at (see end of Appendix for QR code): www.dairynz.co.nz/environment/waterbodies-and-wetlands/riparian-planting/
Channelised flow in vegetated buffer zones (Section 3b): If channelised flow paths develop in vegetated buffer zones, sediment can bypass the buffer and go directly to the watercourse.	**Maintain vegetated buffer zones and grassed setbacks.** To maintain effectiveness, setbacks should be monitored for channelised pathways and may require levelling to ensure runoff leaves the paddock as an evenly dispersed flow.
Overland and preferential flow paths (Section 3c and 3d): These may be caused by topography, slope, soil characteristics, vegetation, land use, or infrastructure. When unmanaged, these flow paths can concentrate runoff, leading to scouring and erosion that transports soil to CSAs. Landscape DNA actions for overland flow can be found here (see end of Appendix for QR code): www.landscapedna.org/  Select 'Actions'. Select 'Overland flow' in the Contaminant Pathway box and 'Arable' in the Land Use box. Select 'See table' to generate a list of actions.	**Interception drains** direct preferential surface water flow paths away from paddocks and CSAs. For example, a **contour drain** running across the slope of a paddock could direct water into a permanent drain at the edge of the paddock, reducing the slope length and erosive power of runoff. **Diversion bunds** are earth bunds constructed across a slope or along a contour to intercept and redirect surface water runoff to paddock edges or drains, preventing it from flowing onto or from a paddock. **Sediment traps** are ponds designed to slow the flow of water, allowing suspended sediment to settle out before water enters downstream waterways. They can be created by excavating a deeper pool within a watercourse or by constructing an embankment across a flow path to temporarily retain runoff. They are usually shallow, relatively simple, and easy to clean out. **Profile of sediment trap (approx 1 metre deep x 13 metre long).**  A video and further information can be found at (see end of Appendix for QR code): www.canterbury.ac.nz/research/about-uc-research/research-groups-and-centres/freshwater-ecology-research-group/carex **Detainment bunds** use a ridge of compacted earth to temporarily pond runoff. Controlled release, at a rate that will allow suspended sediment to settle out, is managed through a riser structure, with an emergency spillway incorporated for extreme events. The impact of temporary inundation on yield of arable crops is currently unknown. Modified designs, such as adjustable risers or multi-stage outlets, may be required to shorten detention periods during critical crop windows. Find out more here (see end of Appendix for QR codes): www.detainmentbund.co.nz/ and www.landscapedna.org/actions/interception/detainment-bunds/ **Constructed wetlands** are highly effective at filtering sediment, nutrients, and other contaminants from drainage water. Small, constructed wetlands such as off-line sedimentation ponds or in-line filtration wetlands, suit arable farms where every hectare of productive land is valuable. A **vegetated buffer zone** may be used to intercept overland flow paths reducing the movement of sediment and nutrients.

Swales and ephemeral watercourses (Section 3e): Swales and ephemeral watercourses are natural drainage pathways that can transport sediment to permanent waterways. An ephemeral watercourse is a channel that only flows intermittently and can be dry for much of the year.	**A vegetated buffer zone** is an effective way of managing the exit point of a swale or swale system, assisting in filtering overland flow from surrounding paddocks. The extended margins can be left in rank grass or planted in native grass species such as red tussock or *Carex secta*. Where relevant, stock exclusion must be factored in. Where appropriate, establishing **permanent plantings** along ephemeral watercourses, such as plantings of *Carex* spp., can provide a robust physical barrier that traps coarse sediment while allowing water to flow. Depending on flows, **constructed wetlands and sediment traps** (see 'Overland and preferential flow paths' above) could be options to consider.
Impervious areas (Section 3f): Impervious areas like tracks and lanes increase surface runoff which can result in scouring and poor crop growth. The volume of water coming off these areas can be underestimated, particularly in heavy rainfall.	**Interception drains** can direct surface water flowing off impervious areas away from paddocks and CSAs. **Vegetated buffer strips** can be used to filter runoff form impervious areas. **Diversion bunds** can be used to intercept and redirect surface water runoff from impervious areas to paddock edges or drains. **Ripping** compacted wheel tracks on heavy clay soils can increase infiltration and reduce erosion allowing water to percolate into the soil rather than flow down the wheel tracks. Wheel track ripping may increase erosion on light volcanic ash soils. **Wheel track diking** uses an implement to create series of closely spaced soil dams in compacted wheel tracks which slows surface runoff water and settles suspended sediment. Further guidance on impervious area management can be found here (see end of Appendix for QR code): www.hortnz.co.nz/assets/Compliance/Erosion-and-Sediment-Control-Guidelines-for-vegetable-production-v1.1.pdf
Poorly placed access ways: Poorly placed access ways can act as discharge points for stormwater to CSAs.	**Position** access ways away from the lowest point where water is naturally diverted or concentrates. Further guidance can be found here (see end of Appendix for QR code): www.hortnz.co.nz/assets/Compliance/Erosion-and-Sediment-Control-Guidelines-for-vegetable-production-v1.1.pdf

How to guides for riparian plantings for you region.

Selecting native plants that attract beneficial insects: A Canterbury Guide.

FAR Focus 15: Good soil is good business.

Variable rate buffer strip information.

Landscape DNA actions for overland flow.

CAREX sediment pond video and further information.

Detainment bunds.

Guidance on impervious area management and position of access ways.

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