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Goldfields Little Creeks Climate Adaptation Strategy and Restoration Guide

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Goldfields Little Creeks Climate Adaptation Strategy and Restoration Guide

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Acknowledgement of Country

Federation University Australia and the Bunanyung Landscape Alliance acknowledge the Traditional Custodians of the lands and waters of the region on which this report focuses – the Wadawurrung People and the Dja Dja Wurrung People. We pay our respects to Elders past and present, and acknowledge the nurture and care of Country for tens of thousands of years, and the ongoing contribution to the management of land, water, and our built environments.

Statement of purpose

The document presents a strategy for the restoration of headwater streams in the Goldfields region. The primary focus of the project is climate adaptation, particularly in the form of cooling down streams and assisting stream fauna and other wildlife to adapt to a changing climate. Achieving such a goal requires many considerations, including the hydrology of streams and the socio-political context in which streams occur. This document will incorporate some of these considerations in its quest to present a strategy for climate adaptation of streams.

The intended audience of this strategy is varied, but primarily includes:

- private landholders who live on land with or near streams
- developers and local government wanting to (1) incorporate healthy streams into town planning and new developments, and (2) reduce the negative effects of new developments on downstream processes
- advocates of climate adaptation and healthy streams

Background

Riparian ecosystems occupy a relatively small proportion of land surface area, but make a disproportionately high contribution to ecological function, biodiversity, and ecosystem services. The suite of functions they provide includes (a) light and temperature control through shading (Davies 2010), (b) nutrient filtration and cycling, (c) sediment trapping and cycling that regulates water quality, (d) bank and bed stabilisation, and (e) biodiversity conservation through provision of aquatic and terrestrial habitat (Capon & Petit 2018). In an urban setting, riparian systems also provide a suite of services that enhance human comfort such as moderating local temperature and humidity and providing amenity for residents. Conversely, degraded riparian ecosystems are associated with many serious environmental problems such as increased river channel erosion, localised increased deposition, altered flow regimes, water-quality decline, increased flood risk, biodiversity loss and increased vulnerability to invasive species. In urban areas, the absence of vegetated riparian corridors contributes to the Urban Heat Island Effect (Torok *et al.* 2001), with consequences for human comfort and sustainable energy use in cities.

Effect of climate change on streams

Much of the literature on stream restoration in previous decades focused on restoring riparian vegetation to a previous reference state, and addressing the threats posed by habitat loss and non-native species invasions. However, streams over the next century will increasingly be subject to global temperature increases, and riparian ecosystems will face increases in air and surface-water temperatures. Stream temperature influences the physical, chemical, and biological properties of streams, including the survival and habitat use by aquatic organisms (Cook et al. 2013). As such, historical conditions can no longer be the benchmark for riparian restoration, and climate adaptation through shading of streams must be incorporated into our restoration goals. Riparian ecosystems also provide linear habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife, all characteristics that can contribute to ecological adaptation to climate change.

Streams in urban environments

Streams in urban settings have particular challenges when it comes to managing water. When vegetation is removed and replaced with a housing development, there is a dramatic increase in the extent of impervious surfaces and a reduction in evapotranspiration, and both factors lead to increased runoff into streams and increased flood risk (Burns et al. 2012; Imberger et al. 2011). A common approach to deal with this is to implement drainage systems that can route stormwater runoff into pipes leading to receiving waters. This can be effective at local scales but presents many challenges for managing healthy waterways and creating comfortable urban environments for human inhabitants. The problems of increased flood risk and rapid water flow are transferred downstream and can compound. Conversely, there are multiple benefits when water moves more slowly though an urban environment and when vegetation is present to absorb and use water.

Water-sensitive urban design

Water-sensitive urban design is a set of principles designed to assist in climate adaptation and improve the outdoor human thermal comfort of urban areas (Coutts et al. 2012). Research demonstrates that in an Australian context, water-sensitive urban design can lower urban temperatures, negating Urban Heat Island effects, and can help to slow water down, cool stream temperatures (Trimmel et al 2018; Thompson & Parkinson 2011) and foster urban biodiversity (Broadbent et al. 2017; Coutts et al. 2012).

Climate adaptation of streams in the Ballarat Goldfields

In the Ballarat Goldfields, climate adaptation of little creeks can be achieved by using riparian vegetation to shade streams on private rural and peri-urban land and in parks and reserves (such as Woowookarung Regional Park), and via the implementation of Water-sensitive urban design in existing and new urban areas. Doing so would have multiple benefits for meeting other regional goals, such as meeting many of the goals in DELWP's *Grampians Region Climate Adaptation Strategy 2021-2025* and the City of Ballarat's *Yarrowee River and Tributaries River Corridor Masterplan 2019/20.* Reduced energy demands in better-moderated local climates would also help contribute to the Ballarat City Council *Carbon Neutrality and 100% Renewables Action Plan 2019–2025*.

Why little creeks?

The focus of this document is the revegetation of little creeks in the Ballarat region. It is a strategy that will complement other strategies and plans that focus on larger waterways. The *Yarrowee River and Tributaries River Corridor Masterplan 2019/20*, commendably, focuses on the Yarrowee River and larger tributaries like Canadian Creek and Union Jack Creek. Similarly, DELWP's Regional Riparian Action Plan (DELWP 2015) provides an aspirational target of improving the condition of 270 km of riparian vegetation in the Corangamite region. However, within the City of Ballarat, the river and creek priorities are currently the Yarrowee River, Williamson Creek, Spring Creek and Lal Lal Creek. Again, this is commendable and necessary but does not target little creeks and tributaries which can play a large role in the climate adaptation of waterways.

There are many little creeks that flow into the Yarrowee or the main tributaries of the Yarrowee that comprise a large proportion of the total length of waterways in the region but might not receive the same level of planning, management, and climate-proofing. Figure 1 demonstrates the large number of little creeks and gullies in the Ballarat region. The Friends of the Canadian Creek identify six important little creeks that are tributaries to Canadian Creek that are not included in the masterplan (FoCC 2020). This document focuses on methods for climate adaptation rather than a specific target such as length of revegetated waterways. As such, while the strategy described here is designed specifically for little creeks, many of the principles described can be applied to larger tributaries and rivers.

The document sets out the background, context, constraints, ecological considerations and strategic aims relating to the restoration of headwater streams in the Goldfields region. A companion document—the *Goldfields Little Creeks Restoration Guide*—will provide a summary of this strategy that can be easily read and distributed.

This strategy recommends modification of stream design in Ballarat's little creeks, such as incorporating meandering and ponding. However, the design elements of stream modification are beyond the scope of this strategy. Any modification of stream design will require consultation with a geomorphologist and/or hydrologist to ensure the intended stream design can cope with peak flows and withstand erosional processes. However, the main principles presented here are intended to slow water down in the landscape, and in general the suggested changes to streams will result in lower peak flows than those exhibited by many streams in the current landscape.

Figure 1. Waterways of the Ballarat region, showing ***(a)*** *the area between Lake Burrumbeet and Lake Wendouree,* ***(b)*** *the area between Ballarat and Creswick, including a large number of creeks and gullies, many of which are tributaries to Burrumbeet Creek,* ***(c)*** *the area between Smythesdale and Smythes Creek, including tributaries to Woady Yaloak River and Winter Creek, and* ***(d)*** *the Canadian Corridor between Ballarat and Buninyong, including tributaries to Canadian Creek and Yarrowee River.* Map source: NRM Planning Portal https://www.ccmaknowledgebase.vic.gov.au/nrmpp/

We consider the evidence of the benefits of riparian restoration and Water-sensitive urban design to be irrefutable. We believe such goals to be very achievable if they are incorporated into the design stage of urban planning, provided there is political will to achieve suitable outcomes for the environment and for the people who live near streams. Hence, one of the aims of this document is to advocate for such outcomes.

Examples of Ballarat's suburban little creeks

This section will highlight nine examples of Ballarat's suburban and rural little creeks, with reference to the main features and outcomes for citizens, biodiversity, downstream processes, and climate adaptation. The purpose of this section is to consider the context in which Ballarat's little creeks occur, and some of the possible outcomes that can be achieved. We acknowledge that each length of stream is subject to a unique set of circumstances and limitations, but these examples should fire the imagination of anyone involved in the planning stages of little creek design or restoration. In our critiques of some of the waterways, we acknowledge that newer sites have not had time for plants to establish themselves.

Example 1. Sailors Gully Creek

Example 1 is the riparian vegetation and stream design of the creek informally known as Sailors Gully Creek (Figure 2). The highlighted section is along Hocking Avenue in Mount Clear, and it is an excellent example of Water-sensitive urban design that achieves climate adaptation, habitat for biodiversity and amenity for local citizens. It receives runoff from Woowookarung Regional Park and flows west into Canadian Creek. Engineering of the waterway has allowed for ponding (Figures 1a–d) and meandering of the stream. The result is slow water movement through the landscape. Overstorey trees include both retained remnant trees and planted trees, and they provide shade over the stream and the ponds through much of the day. Streamside and in-stream vegetation include several sedge and rush species, aquatic herbs and floating water ferns. There are some midstorey and low shrubs, but there is scope to improve the complexity of the vegetation by adding midstorey plantings.

The stretch of creek has also been sensitively designed to consider human amenity. There are multiple places to cross the creek where the creek travels through a pipe for short sections. There are public benches and a well-developed walking track along the creek. The creek is also a pleasant place to be – there is much to look at, the sounds of birds and frogs create an attractive soundscape, and on a warm day it is cool by the creek.

Figure 2. Sailors Gully Creek, Mount Clear. **a** *and* **b** *show ponding along the creek with shading from trees and riparian and aquatic vegetation.* **c–d** *show elements of infrastructure to facilitate enjoyment of the waterway by citizens, including railing along walkways, crossing points and shaded seating.*

Example 2. Wattletree Creek

Example 2 (Figure 3) is the section of the creek informally known as Wattletree Creek that can be accessed via the playground on Oakbank Drive, Mount Helen. The overstorey is very well developed and cloaks a high proportion of the stream in deep shade for much of the day. The riparian vegetation is also relatively wide, manifest as a 25–30-m wide strip of overstorey vegetation along much of the stream, which provides excellent habitat and additional shade for the stream when the incoming sun is at oblique angles, as well as moderation of the local climate.

Unlike Example 1, this stretch of creek is at the back of residential properties on either side, so it is more hidden and wilder. The understorey is highly infested by weeds. Blackberry has been sprayed but maintains a stronghold. There are exotic midstorey species like hawthorn (*Crataegus monogyna*). Nevertheless, there are sections of native perennial grass that remain relatively weed free. There is no infrastructure to aid amenity of the creek but the potential exists for a walking track that would rectify this.

Figure 3. Wattletree Creek, Mount Helen. **a–d** *show dense vegetation with high canopy cover and mix of native and exotic understorey.* **e** *shows the outer edge of the vegetated strip from the parkland on Oakbank Drive.*

Example 3. Lal Lal Drain

Example 3 is the section of Lal Lal Drain that runs west towards Joseph St, Canadian, upstream of a piped section of the creek. The stream bank has been planted out with native shrubs, though they have been planted into compacted soil and their fate is uncertain. There has been significant downcutting by erosion. Some sections of the stream are shaded by native trees and shrubs or by pine. The stream is very straight; there is potential for additional meandering of the stream and some ponding to slow the water down and provide habitat for native fauna. A park next to the photographed section provides the opportunity of space for some ponding. The section to the east runs behind residential properties on the south side and hence is somewhat limited for space to meander, but there are some opportunities to slow the water down with ponding. There is also potential to increase amenity with a walking track that could be linked to other tracks in the area.

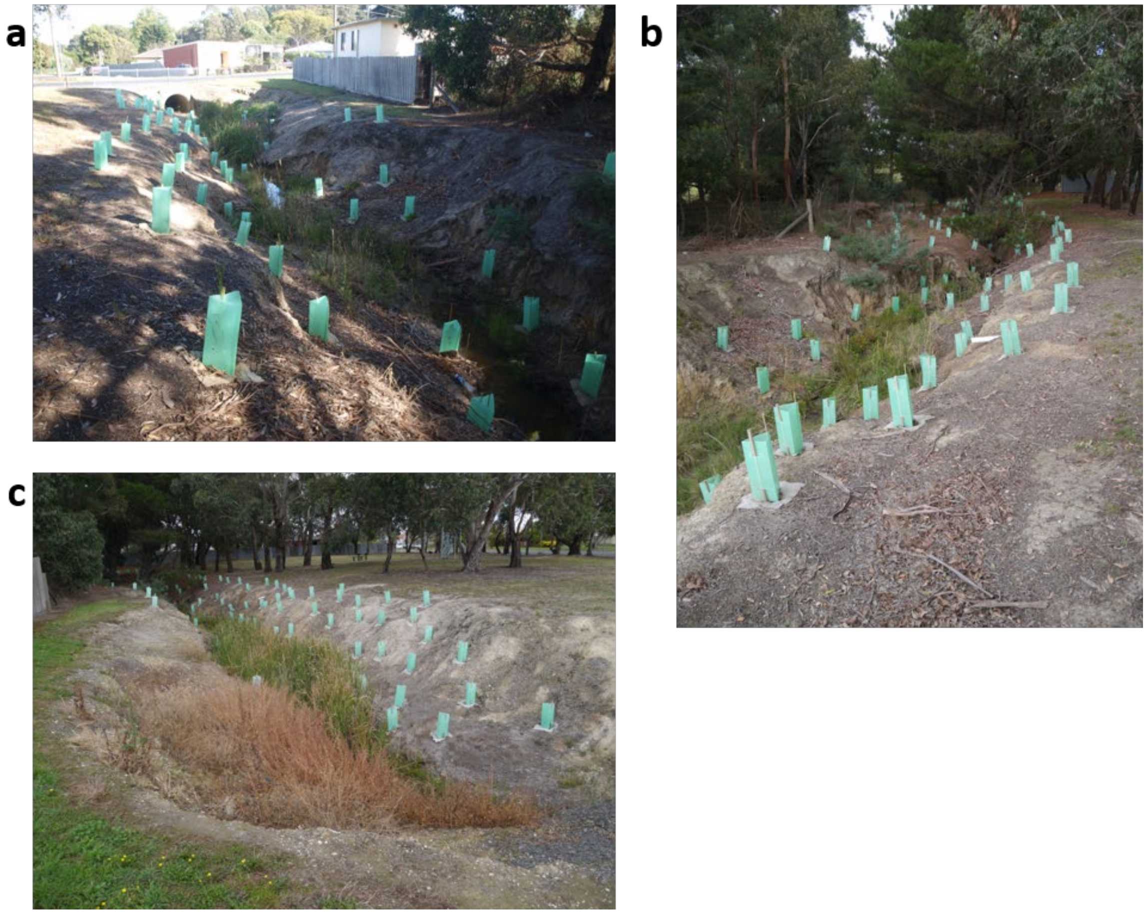

Figure 4. Lal Lal drain, Joseph St, Canadian. **a–c** *show the steeply downcut creekbank that has been planted with tubestock of trees and shrubs.*

Example 4. Lal Lal Drain 2

Example 4 is a stretch of stream running west into Canadian Creek from Larter St, Canadian. This stretch of stream is treeless, unshaded, and straight. It receives water that has meandered through the previous stretch of Lal Lal drain. The stream bed has been colonised by bulrush (*Typha domingensis*). The residential units on the north side are quite close to the stream. There is significant potential to improve this stream on several fronts:

- improve climate adaptation of this stream with shade trees
- increase habitat value with shrubs, groundstorey vegetation and aquatic vegetation
- improve downstream processes with meandering and pooling to slow the stream on the southern side
- increase amenity through all the above.

This length of stream is accessible from the Sovereign Hill car park, and so is highly visible to a large number of visitors to Ballarat, and has significant potential to showcase Water-sensitive urban design.

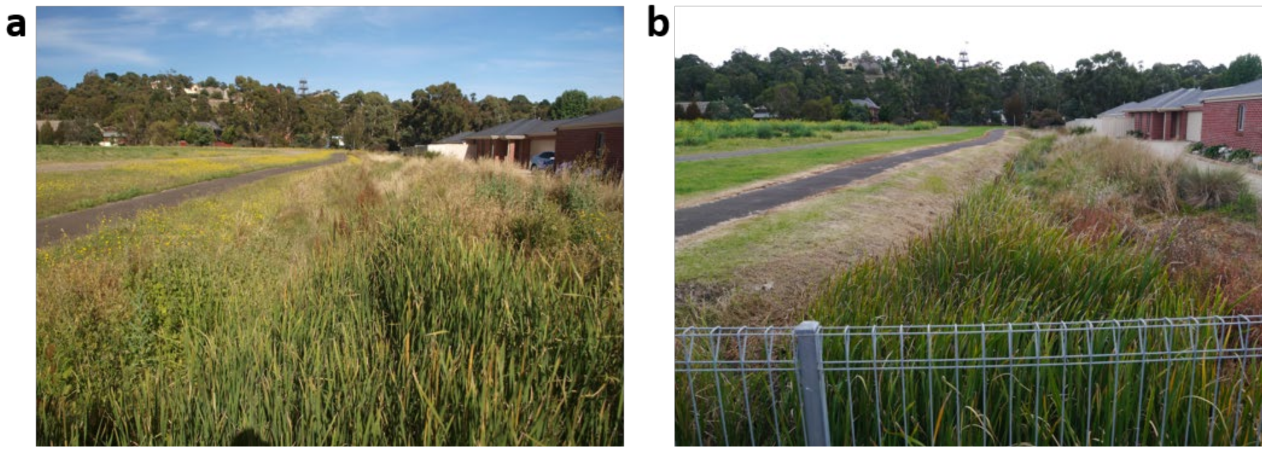

Figure 5. Lal Lal Drain, Larter St, Canadian. a–b *both look west towards Sovereign Hill, and show a straight, exposed stretch of creek. The creek bed is colonised by bulrush.*

Example 5. Pennyweight Gully

Example 5 (Figure 6) is a newly landscaped length of stream along Spencer St, Canadian, with a road and new housing development to the west and a raised rail-trail bike and walking path on the east (Figure 6f). The final plan for this length of stream is unclear, but even if it were to be planted out with native species, it is very straight with little potential for meandering. The stream will likely receive a lot of runoff from the surrounding urban landscape that is highly impervious. It seems the stream may struggle to handle the sediment load and peak flows it is likely to experience—Figure 6a demonstrates significant build up of sediment at the drain which has since been cleared (Figure 6b).

Figure 6. Pennyweight Gully. **a** *shows the build up of sediment at the drain, that was subsequently cleared (shown in b).* **c–e** *show the straight, unvegetated stretch of gully.* **f** *shows a raised rail-trail bike and walking path to the east of the gully.*

Example 6. Fellmongers Creek

Example 6 is a stretch of Fellmongers Creek in Pootilla on private property designated as farming zone. Figures 7b and 7c show two stretches with plantings by the Wattle Flat Pootilla Landcare Group. The planting has multiple goals: to connect two sections of native vegetation (shown by points 1 and 5 in Figure 7a), to shade the stream, and to provide habitat for birds and small mammals. Figure 6d shows a stretch without planting on an adjoining property, which presumably will remain unshaded. This example demonstrates how a local group can take action to help adapt headwater streams for future climates. Another excellent example of what can be achieved by revegetating small streams on rural properties is the Dewing Creek Waterway Protection Project.

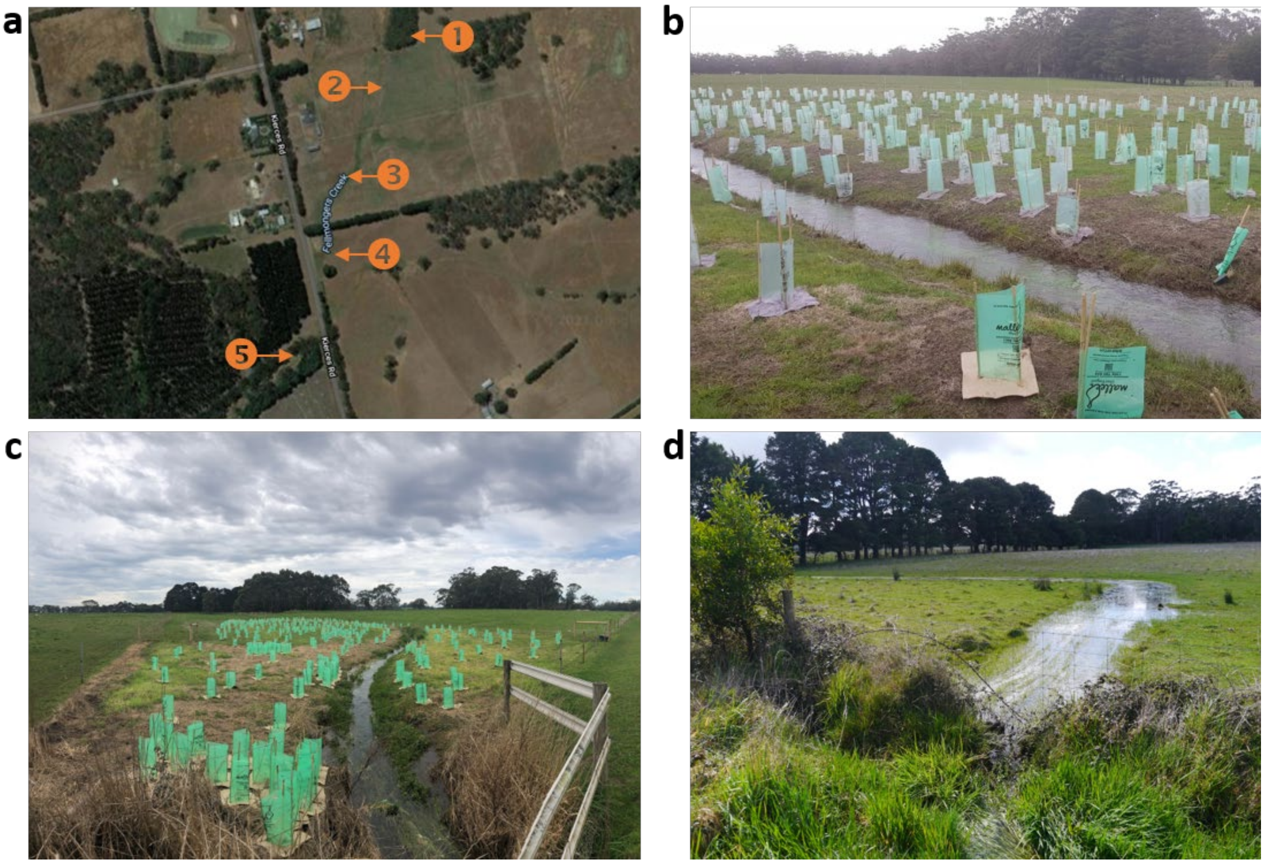

*Figure 7. A stretch of Fellmonger's Creek, Pootilla, that has been targeted for restoration. The numbered arrows in **6a** refer to the following: ❶ and ❺ show the native vegetation to the north and south of the targeted area, respectively, and ❷, ❸ and ❹ show the locations of the photos in **6b**, **6c** and **6d**, respectively (Photo credit for b and c: Wattle Creek Pootilla Landcare Group).*

Example 7. Kensington Creek

Example 7 is Kensington Creek (Figure 8) where it runs along The Ridge (a street in Delacombe), north of Delacombe town centre, in a relatively new housing development. Whilst aspects of Water-sensitive urban design have been incorporated by planting filtering sedges and reeds, which help maintain water quality and prevent erosion, there are areas that remain in a degraded state, compromising the potential ecological function of the waterway. Tall trees are present in the surrounding park land but are not close enough to the creek to provide effective shading. An infestation of hemlock is apparent in areas that remain devoid of native plants. There is evidence of downcutting, particularly in the more linear sections, but adequate space exists to incorporate meandering. A shrub layer would increase amenity for local residents and provide habitat and resources for birds. The City of Ballarat has installed a sign to ensure awareness and safety regarding potential snake presence, which is a positive step towards communicating with the public about the importance of biodiversity.

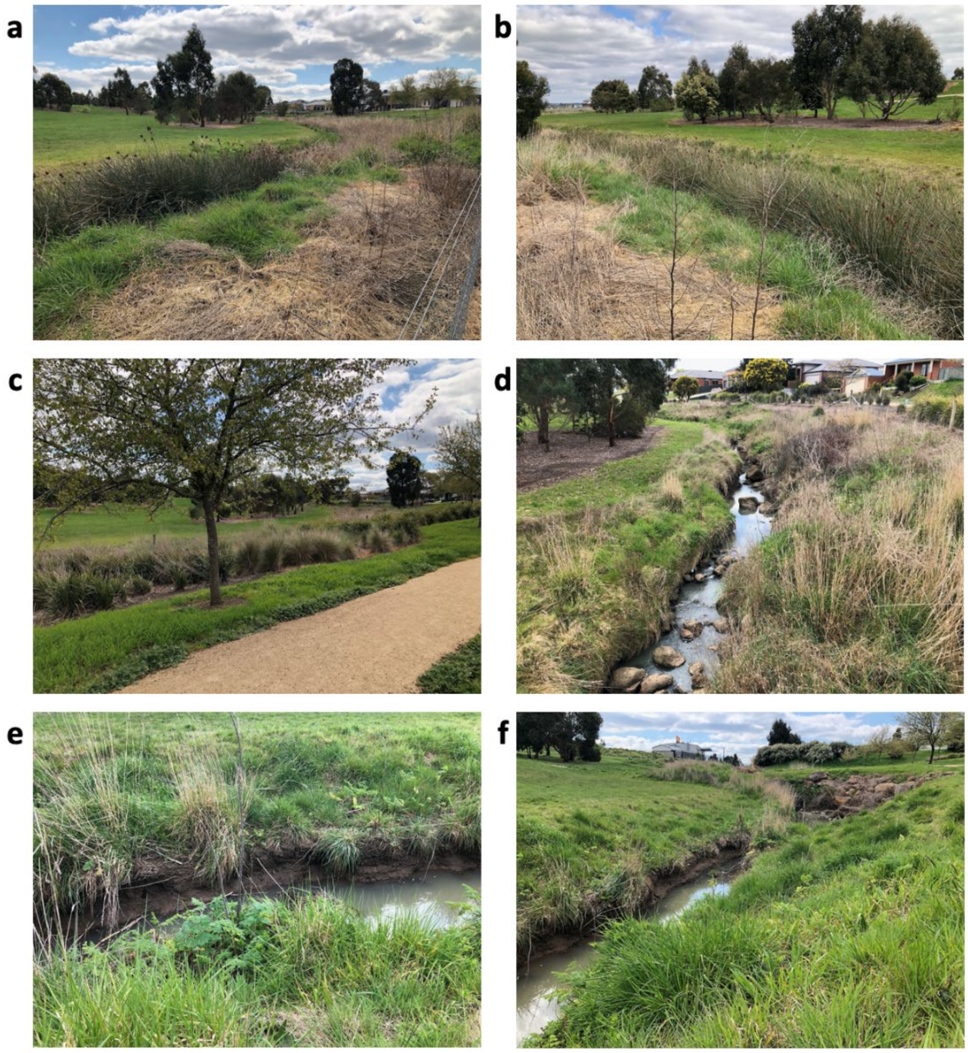

Figure 8. Kensington Creek. **a–f** *show stretches of the creek that are relatively unshaded and show significant downcutting of the stream bank.*

Example 8. Bonshaw Creek

Example 8 is Bonshaw Creek (Figure 9) as it runs from Ascot Gardens Drive, Bonshaw. The creek is near a current and expanding housing development. A significant vegetation and waterway restoration project is under way, commendable in its scale and ambition. The reserved area is wide enough to allow considerable meandering, and planted vegetation is at densities that could provide excellent shading and habitat structure in the future. As the vegetation matures it will moderate water temperature and help maintain important habitat for aquatic organisms. Further, the space is likely to provide significant amenity and cooling for residents. Extensive walking paths, a bridge across the creek, and well-placed seating are creating opportunities for people to experience the recreational, cultural and social benefits of the natural environment. Weed infestation is a potential threat, and the fate of the plantings should be monitored.

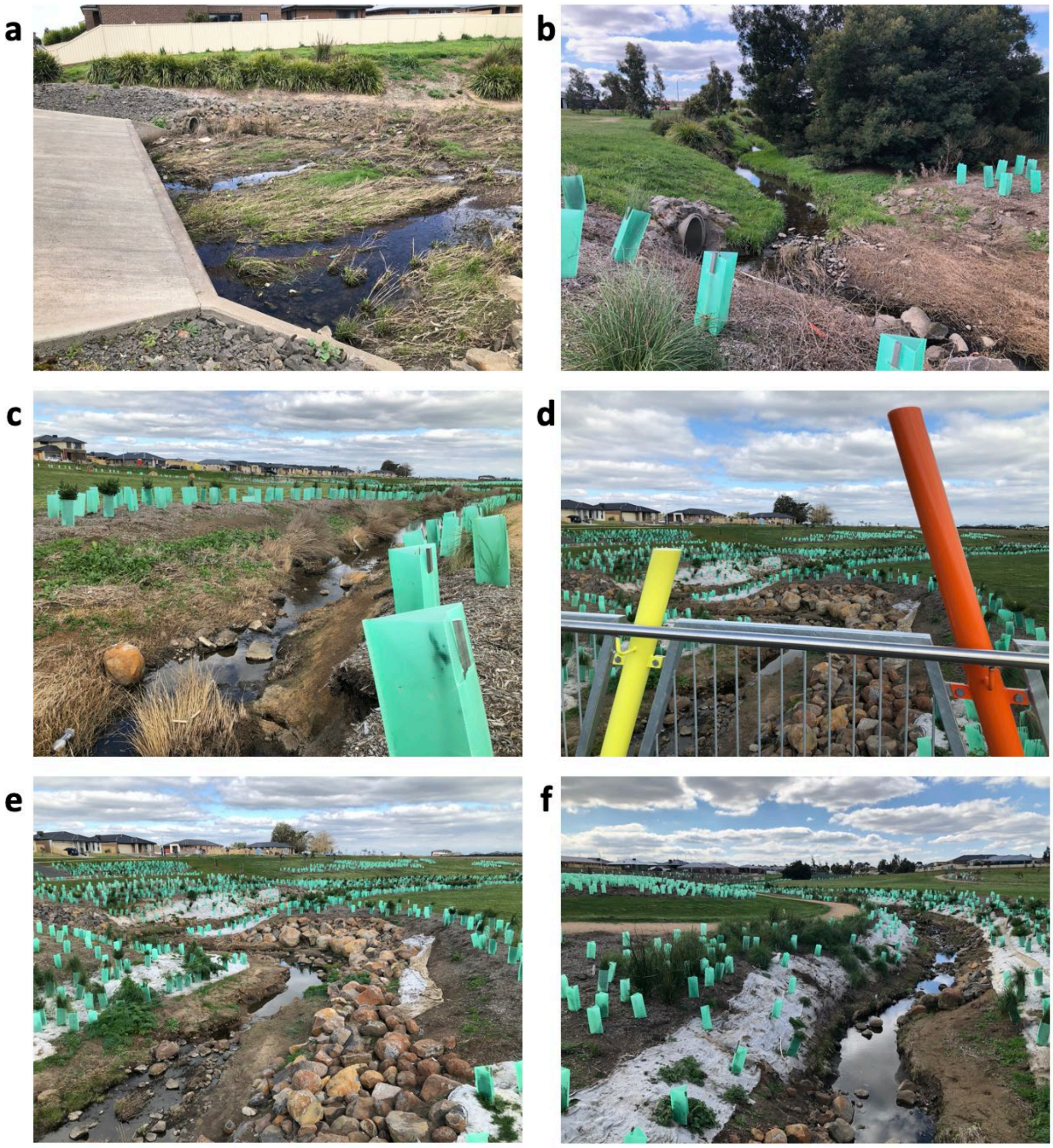

Figure 9. Bonshaw Creek, a small creek running through and near new housing developments in Bonshaw. a–f show the placement of rocks to slow the stream and encourage meandering, and substantial planting of tubestock to stabilise the bank and provide future shading of the stream.

Example 9. Moss Avenue

Example 9 is a small roadside creek along Moss Avenue in Mount Helen in an area of low-density residential and farming properties. Water from this little creek feeds into the Yarrowee River. Remnant *Eucalyptus* and *Acacia* trees provide good-quality shading to a section of this waterway making considerable improvement realistic and achievable. This is a good candidate for a Landcare project where weed management is followed by supplementary planting of a shrub layer to complement existing trees, provide additional and more diverse bird habitat, and improve climate adaptation. Although the strips of vegetation running parallel to the creek (the roadside and the adjoining private land) are relatively narrow, the vegetation can still act to filter run-off and buffer the creek from traffic pollution and increasing air temperatures. The surrounding landscape is more pervious than in many of the urban examples. Revegetation could be extended to better connect the north-eastern portion of the creek where water is collected, down to the less vegetated, lower-elevation roadside of the south-western section to join up with Ballarat Steiner School.

Figure 10. Moss Avenue. **a–d** *show a small roadside creek with a well-developed native overstorey but a weed-dominated understorey.*

Goals of the strategy

What should we be trying to achieve?

We have highlighted the context in which Ballarat's little creeks are situated. We believe the following goals are achievable and should be incorporated at the planning stages for Ballarat's little creeks:

- Shading of creeks to moderate water temperatures
- Moderating water velocity though landscape and stream design
- Providing habitat for native fauna
- Providing amenity for local citizens
- Moderating local climate to improve human comfort levels.

The strategy

Stream design and trajectory

Technical detail on the design of stream trajectory is beyond the scope of this strategy. *A Rehabilitation Manual for Australian Streams* by Rutherfurd et al. (2000) represents the work of over 60 contributing scientists. The design of stream trajectory for any length of stream requires many considerations and should be done on a case-by-case basis in consultation with geomorphologists and hydrologists. In Victoria, Catchment Management Authorities are responsible for coordinating programs to enhance streams, and this includes working with landholders, managers, and community groups on issues such as revegetation and bank stabilisation. The Corangamite CMA achieves this, in part, through their Water Protection Program (link here), and we encourage stakeholders that are considering changes to stream design and trajectory to contact their CMA. Nevertheless, we can cover some general principles here for consideration, with a focus on some of those pertinent to the Ballarat region.

From a planning perspective, we cannot escape the reality that a wider stream provides more opportunity for meandering (or sinuosity), which will help achieve the goal of slowing water down. In the case of streams in an urban setting, the dedication of space to a wider stream can be highly problematic but we advocate strongly that space for an urban stream be incorporated into the planning stages of urban development, and that this space would be key to achieving the many goals of having healthy urban waterways. Any serious plan to have healthy, climate-adapted, and biodiverse waterways in the Ballarat region will need to grapple with this important challenge to stream design.

Stream trajectory will naturally self-adjust to slow the velocity of water if the sides of the stream are erodible (i.e. not bedrock). However, in many cases the rate of this process is not commensurate with the time scales required to achieve acceptable urban stream outcomes in an urban setting. As such, it will often be preferable to reconfigure a stream trajectory with earth works to more rapidly achieve relative equilibrium of stream trajectory that will cope with the inputs of water to the stream.

It is worth noting here that the current trajectories of many of Ballarat's little creeks do not reflect their historical trajectory. Streams have been diverted and modified by human disturbances such as mining, farming, and urban development. This again reinforces the notion that the goal of little-creek restoration in the Ballarat region should be to create novel riparian systems that are functional and that achieve the goals agreed upon by multiple end users. We should not be too precious about the current stream trajectories, particularly those that do not currently achieve the goals of climate adaptation, biodiversity conservation and amenity. One important caveat is the case of large remnant trees. Remnant trees are a significant natural asset that cannot be replaced in the short term, and all efforts should be made to retain large remnant trees in the design and reconfiguration of streams.

Dams

Dams can significantly reduce downstream flow, impacting water quality and temperature. Passing flows are one way to reduce the impact of dams on downstream processes, though some dams do not have the outlet capacity to deliver flows large enough to improve downstream processes, and improving dam infrastructure can be expensive. The *Victorian Waterway Management Strategy* (DEPI, 2013) addresses the impact of dams on environmental flows.

Soil contamination

Many of Ballarat's little creeks feature sludge deposits—a result of the gold rush mining practices—and these are an additional concern for the restoration of creeks in the Ballarat region. Sludge deposits vary in quality, but can contain high levels of arsenic, mercury, and cyanide. Any development or earthmoving works along Ballarat's little creeks must be aware of the presence of sludge deposits and the risk they may pose to stream and human health.

Refuge for fish populations

Ballarat's little creeks are also likely to act as important refugia for small-bodied fish species, some of which are rare or threatened. Many small-bodied fish species in south-eastern Australia are threatened by predation from brown trout. In the Yarrowee river system, brown trout threaten populations of galaxiid fish, such as *Galaxias ornatus, G. oliros* and *G. maculatus*. There are opportunities for rehabilitated little creeks to provide refuge for populations of fish that struggle to maintain populations in the larger, trout-infested streams of the region. One technique is to install in-stream barriers to the passage of trout into the smaller tributaries, creating trout-free 'galaxiid zones' and translocating populations of fish to restored little creeks. This process has been described by Raadik (2014), and such strategies hold significant potential for conservation of fish diversity in the region and could provide another flagship species to engage local communities in the health of little creeks in their area.

Habitat for rare and threatened species

There are other fauna species, including rare and threatened species, that could benefit from having potential habitat restored. This could be an additional consideration for stream design. Two examples include the growling grass frog (*Litoria raniformis*; FFG-listed and EPBC-listed) and the brown toadlet (*Pseudophryne bibronii*). Indeed, attention to such habitat requirement might provide a source of funding for creek restoration through funding schemes such as the Australian

Government's Environment Restoration Fund (https://www.awe.gov.au/environment/biodiversity/conservation/environment-restoration-fund). Similarly, there are rare and threatened plant species that may also find suitable habitat in restored riparian vegetation, though in most cases this would require active introduction to sites.

Community concerns

We appreciate that riparian revegetation is associated with several community concerns about the safety and aesthetics of their surroundings. We address some of these below.

Fire risk

Citizens are often concerned by a perceived increase in fire risk due to the addition of native vegetation close to homes. Whilst we acknowledge that many species of native flora can be prone to fire, it is also important to note the cooling effect delivered by shade provided by such vegetation. Healthy creeks and gullies can act as fire breaks and will be critical in reducing the effects of climate change felt within residential areas. Further, the composition of species (and related diversity in the landscape) will assist with bank stabilisation and effective water-uptake by vegetation, thereby increasing its fire resilience. The inclusion of soft-leaved wet-forest species such as Hazel Pomaderris provides a counterpoint to the more flammable hard-leaved *Eucalyptus* species and promotes mosses and liverworts to thrive at ground level, improving rainfall infiltration and cooling, and moderating the intensity of any fire.

Snakes

The arrival of snakes close to housing may occur once revegetation is established as higher-quality habitat and other resources become available for native species. However, the potential for snake presence should not be a deterrent to shading creeks with native vegetation. Snakes are an important contributor to biodiversity and food-web function. Snakes prefer to avoid human contact and the benefits of snake presence extend to invasive rodent control. Public awareness and education on appropriate caution towards snake presence is an important consideration for councils and developers.

Exotic tree removal

Some residents may object to exotic trees being removed because they currently provide resources to native bird species and some shading for creeks, leaving a significant gap between time removed and establishment of new vegetation. Such removal may mean a reduction in biodiversity and counteract the cooling effect. Revegetation plans should consider the possibility of gradual removal of invasive trees where possible, whilst the new vegetation has time to establish. Further, some exotic species are appropriate to leave in the landscape as their benefits will outweigh the ecological or recreational cost of their removal, but this must be decided on a case-by-case basis.

Flood

Residents and business owners occupying areas near waterways may believe that a clear, linear drain is the best way to take up and transport excess rainwater away from their property. They might perceive new vegetation as an impediment to water management. However, carefully planned creek restoration can significantly mitigate flood risk. Slowing water flow so that it can infiltrate pervious surfaces results in more moisture retention, healthy resilient vegetation, and mitigation of flood at the site and, importantly, downstream. In some circumstances, a secondary channel to the main, vegetated creek might provide additional assurance that water can be removed successfully during peak flows.

Ecosystem design

What types of ecosystems should we be aiming to restore for Ballarat's little creeks?

Before we discuss species selection, it is worth exploring the principles that might guide the overall ecosystem design for Ballarat's little creeks. We can use Victoria's Ecological Vegetation Classes (EVCs; DELWP 2020) to help inform the revegetation of Ballarat's little creeks. Each EVC relates to a benchmark that describes its typical floristic composition, ecological characteristics, and environmental attributes. Each EVC benchmark relates to a single EVC within one bioregion. Ballarat is in an unusual situation in that the landscape represents a complex interfingering of two bioregions, the Central Victorian Uplands and the Victorian Volcanic Plain. For simplicity, we will be using the EVC benchmarks for the Central Victorian Uplands for this report, as this bioregion contains most of the little creeks in the target area.

We advocate that the mapping of pre-1750 EVCs **should not** be assumed to be the most appropriate target for a restored or rehabilitated stream. One of the well-documented impacts of urbanisation surrounding streams is the increase in impervious surface area, and as a result, increased runoff to the receiving streams. As such, a stream in an urban environment is a novel ecosystem that may bear little resemblance to its pre-disturbance state. Planning for the stream should incorporate the natural landscape features and upstream processes that determine water flow, and, importantly, the novel local conditions that determine the amount and timing of water received locally by the stream. Planning should also incorporate adaptation to future climates, ecological function of the waterway, biodiversity targets for the area, and the desired outcomes for residents.

In many cases, urban streams will receive more water than historical streams through the same catchment, increasing the imperative to slow the flow of water through meandering and pooling. This, in turn, will influence species selection. For example, the mapped EVCs for Canadian Creek and its tributaries are Valley Grassy Forest and Heathy Dry Forest. However, the amount of runoff received by these creeks when highly urbanised is likely to be higher than would be expected for those systems. Elements of those EVCs will certainly be suitable, but it would be wise to also incorporate species suited to wetter or more regularly inundated areas.

Accordingly, we advocate that species selection and ecosystem design should be informed by a combination of:

- Suitability for the novel conditions the stream will experience
- Ability of the species to meet the goals of stream restoration and climate adaptation
- Native plant conservation
- Providing habitat for native fauna
- Human desire – what sort of vegetation will provide a comfortable and pleasing urban environment?
- Planning for landscape heterogeneity (discussed below).

We suggest that EVC benchmarks should be used as a framework for restoration only insofar as they also satisfy the above criteria, and that modifications of the EVC benchmarks to meet these criteria might be necessary. For example, we might be guided by the benchmark tree cover of an EVC, but we might opt for cover 5–10% greater than that to help meet our goal of shading the stream for climate adaptation.

The most relevant EVC for riparian restoration in the area is *EVC 83 Swampy Riparian Woodland*, which has a bioregional conservation status of endangered. This is the mapped EVC along the Yarrowee between Ballarat and Scotchmans Lead. Smaller creeks and tributaries might be more suited to *EVC 47 Valley Grassy Forest*. However, as discussed above, additional water shed by impervious urban developments might make smaller creeks and tributaries more suited to *Swampy Riparian Woodland* than their position in the landscape has previously dictated.

There are also opportunities to incorporate elements of several EVCs, depending on the landform and soil type. For this strategy, we will focus on the following EVCs of the Central Victorian Uplands, each of which occurs, or is considered to have occurred, along waterways in the Ballarat region:

- EVC 198 Sedgy Riparian Woodland
- EVC 164 Creekline herb-rich woodland
- EVC 851 Streambank shrubland.

Based on the goals for the restoration of Ballarat's little creeks, the essential components of riparian restoration are summarised in Table 1.

Table 1. *Main components of vegetation structure for riparian restoration of Goldfields little creeks.*

Vegetation structural component	Description	Function	Goal
Overstorey trees	Tall trees	Shading of stream	Moderate water temperature; provide habitat for terrestrial species; improve habitat for aquatic species
Midstorey trees and shrubs	Small trees and shrubs, including prickly shrubs	Habitat for birds; shading of stream (especially smaller streams)	Moderate water temperature; biodiversity conservation
Ground storey species	Perennial grasses, herbs and prostrate shrubs	Exclusion of weeds	Improve resilience of ecosystem; biodiversity conservation
Aquatic and semi-aquatic plants	Perennial graminoid species	Habitat for aquatic species; in-stream habitat; bank stabilisation; water filtration	Self-sustaining aquatic ecosystem

Landscape heterogeneity

We do not want all riparian vegetation in Ballarat to be the same. The contribution of riparian vegetation to the regional plant-species pool will be higher if there is variety in the suites of species that are used to restore riparian vegetation. Such variety would extend to the types of habitats and resources provided for native fauna, in turn, increasing the contribution of riparian habitats to regional fauna diversity.

Stream revegetation planning

Planning for a restoration project is essential. Planting must occur in the appropriate season, and this dictates the timing of site preparation. Some general principles of stream restoration planning specific to the Ballarat region will be presented here.

Nursery access

Widespread adoption of riparian restoration efforts will require a supply of tube stock that is:

- of local provenance, with an adequate diversity of species
- of high-quality plants that are disease free
- not overgrown or root bound
- hardened to local conditions.

Producing such tube stock and having it available at the desired time of planting requires specialist knowledge and a dedicated nursery. Such nurseries exist in Ballarat, but this capacity may not be sufficient to significantly up-scale riparian plantings, while some parties might currently experience difficulties securing the tube stock required for a restoration project. We advocate that a plan to significantly improve the climate adaptation of little creeks should include planning for an adequate supply of tube stock. The Florabank Guidelines provide a guide to nursery practices as well as site preparation.

Species selection

We can now discuss the main guiding principles for species selection within the context of the principles of ecosystem design stipulated above. A precise description of the appropriate species for any location withing the Ballarat Goldfields is beyond the scope of this report. Any restoration effort, particularly larger efforts, should involve consultation with an ecologist of someone with local knowledge of species. Nevertheless, we provide a guide below, and species should be selected within the context of the ecosystem design guidelines provided above. Not all species suggested in the following section will be suitable at all locations across the region, and the tables do not preclude the inclusion of other local species that can fulfil the restoration goals.

How many plants?

The benchmark cover of trees in each of the target EVCs is shown in Table 7. The cover of canopy trees, understorey trees, medium shrubs, small shrubs and perennial graminoids does not vary much among these systems. For this revegetation strategy, we propose the development of generalised cover target for each of these lifeform categories that is marginally higher than the values stated in the EVC benchmarks. This acknowledges one of the main goals of the strategy (shading of streams), the novel ecosystem status of the areas to be restored, and the predicted effects of climate change that increase the imperative to shade streams. Table 2 proposes the target cover value of each life form component, and the density of plants that should be planted to achieve this. It is assumed that all revegetation will be achieved via tube stock planting.

Table 2*. The target cover and planting density of vegetation structural components for the restoration of Goldfields little creeks.*

Vegetation structural component	Target cover (%)	Plant density (plants/ha)
Overstorey trees	25	250
Understorey trees	10	100
Medium shrubs	20	500
Small shrubs	5	250
Large graminoids	10	500

For perspective, 250 plants/ha is equivalent to 25 plants in a 20 m × 50 m strip. The suggested density of planting of small shrubs and large graminoids is less than the density to achieve the target cover suggested by DELWP (DSE 2006). However, we have proposed a lower density of plants in these categories for the following reasons:

- These life forms are less pertinent to the goal of shading streams
- To moderate the cost of revegetation plantings
- Because these life forms might be the target of future additional plantings within the site once the taller life forms have established.

Trees

The overstorey trees targeted for restoration sites are listed in Table 3, according to the chosen EVC benchmark for the restoration. Subcanopy trees are listed in Table 4. For the subcanopy trees, *Allocasuarina verticillata* is not dominant a component of any of the targeted EVC benchmarks, but it has been included here as attractive tree that provide shade and other resources, and to allow greater diversity and heterogeneity in the restoration planting.

Table 3. *Overstorey trees for restoration of Goldfields little creeks. Numbers refer to Ecological Vegetation Classes.*

Scientific name	Common name	47	83	164	198	851
Eucalyptus melliodora	Yellow Box	*				
Eucalyptus obliqua	Messmate Stringybark	*			*	
Eucalyptus ovata	Swamp Gum		*	*	*	
Eucalyptus radiata ssp. *radiata*	Narrow-leaf Peppermint	*		*	*	
Eucalyptus rubida	Candlebark	*		*		
Eucalyptus viminalis	Manna Gum			*		

Table 4. *Subcanopy trees for the restoration of Goldfields little creeks. Numbers refer to Ecological Vegetation Classes.*

Scientific name	Common name	47	83	164	198	851
Acacia dealbata	Silver Wattle	*		*		
Acacia mearnsii	Black Wattle	*	*			*
Acacia melanoxylon	Blackwood	*	*	*	*	*
Allocasuarina verticillata	Drooping She-oak					

Shrubs

The shrubs targeted for restoration have been divided into medium shrubs (Table 5) and small and prostrate shrubs (Table 6). The composition of shrubs is generally more diverse than that of trees, and a range of shrubs should be included in any planting. The medium shrubs have been divided into spikey and non-spikey shrubs, and we advocate that spikey shrubs should be incorporated into all plantings due to their particularly high value as bird habitat.

Table 5. *Medium shrubs for the restoration of Goldfields little creeks, divided into spikey and non-spikey categories. Numbers refer to Ecological Vegetation Classes.*

Scientific name	Common name	47	83	164	198	851
Spikey shrubs						
Acacia verticillata	Prickly Moses		*		*	*
Bursaria spinosa	Sweet Bursaria	*		*		*
Coprosma quadrifida	Prickly Currant-bush				*	
Leptospermum continentale	Prickly Tea-tree			*	*	
Acacia pycnantha	Golden Wattle	*				
Non-spikey shrubs						
Bossiaea cordigera	Wiry Bossiaea				*	
Callistemon sieberi	River Bottlebrush					*
Cassinia aculeata	Common Cassinia					*
Daviesia leptophylla	Narrow-leaf Bitter-pea	*				
Dodonaea viscosa s.l.	Sticky Hop-bush		*			*
Epacris impressa	Common Heath	*			*	
Goodenia ovata	Hop Goodenia				*	
Hymenanthera dentata s.l.	Tree Violet					*
Leptospermum lanigerum	Woolly Tea-tree		*		*	*
Myoporum sp. 1	Sticky Boobialla	*				
Olearia glandulosa	Swamp Daisy-bush		*			
Ozothamnus rosmarinifolius	Rosemary Everlasting		*			
Pultenaea daphnoides	Large-leaf Bush-pea			*		

Table 6. *Small and prostrate shrubs for the restoration of Goldfields little creeks. Numbers refer to Ecological Vegetation Classes.*

Scientific name	Common name	47	83	164	198	851
Acacia aculeatissima	Thin-leaf Wattle	*				
Dillwynia cinerascens s.l.	Grey Parrot-pea	*			*	
Hovea heterophylla	Common Hovea	*				
Olearia erubescens	Moth Daisy-bush				*	
Pimelea humilis	Common Rice-flower	*				
Rubus parvifolius	Small-leaf Bramble		*			
Acrotriche serrulata	Honey-pots	*		*		
Bossiaea prostrata	Creeping Bossiaea	*				

Other species

The City of Ballarat provides a guide to local native species that includes additional species for consideration: https://www.ballarat.vic.gov.au/city/parks-and-outdoors/indigenous-plants

There are also opportunities to incorporate plant species of cultural significance or rare and threatened species into a revegetation plan. In addition to the intrinsic value of establishing new populations of such species, this strategy could also serve to engage the community in the stream and its vegetation. Interpretative signs about the vegetation can increase community understanding of riparian vegetation and increase their personal investment in the health of the stream.

Post-planting

Investment in watering tube stock after they have been planted can significantly improve the survival of tube stock. Broadbent et al. (2017) showed that in Adelaide, irrigated or well-watered streamside trees provided better canopy cover than those without watering.

Monitoring

Monitoring the outcomes of stream restoration activities is an important aspect of this strategy. Monitoring allows the testing of assumptions about the benefits of stream restoration, so that an adaptive management approach can be used to continually improve stream restoration techniques.

The following are elements of stream health and restoration success that would be beneficial to monitor in the months and years after a restoration effort:

- Water temperatures
- Water flow rates (average, minimum, maximum)
- Other stream parameters (turbidity, water quality, etc)
- Projective foliage cover of shade
- Success of tube stock planting, including the relative success of different species
- Stream invertebrate community composition
- Faunal surveys (birds, frogs, mammals)

It would also be beneficial to monitor the attitudes and engagement of residents to stream restoration activities, including their awareness, concerns and beliefs about the stream and its vegetation, and the level of amenity that the stream restoration provides.

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