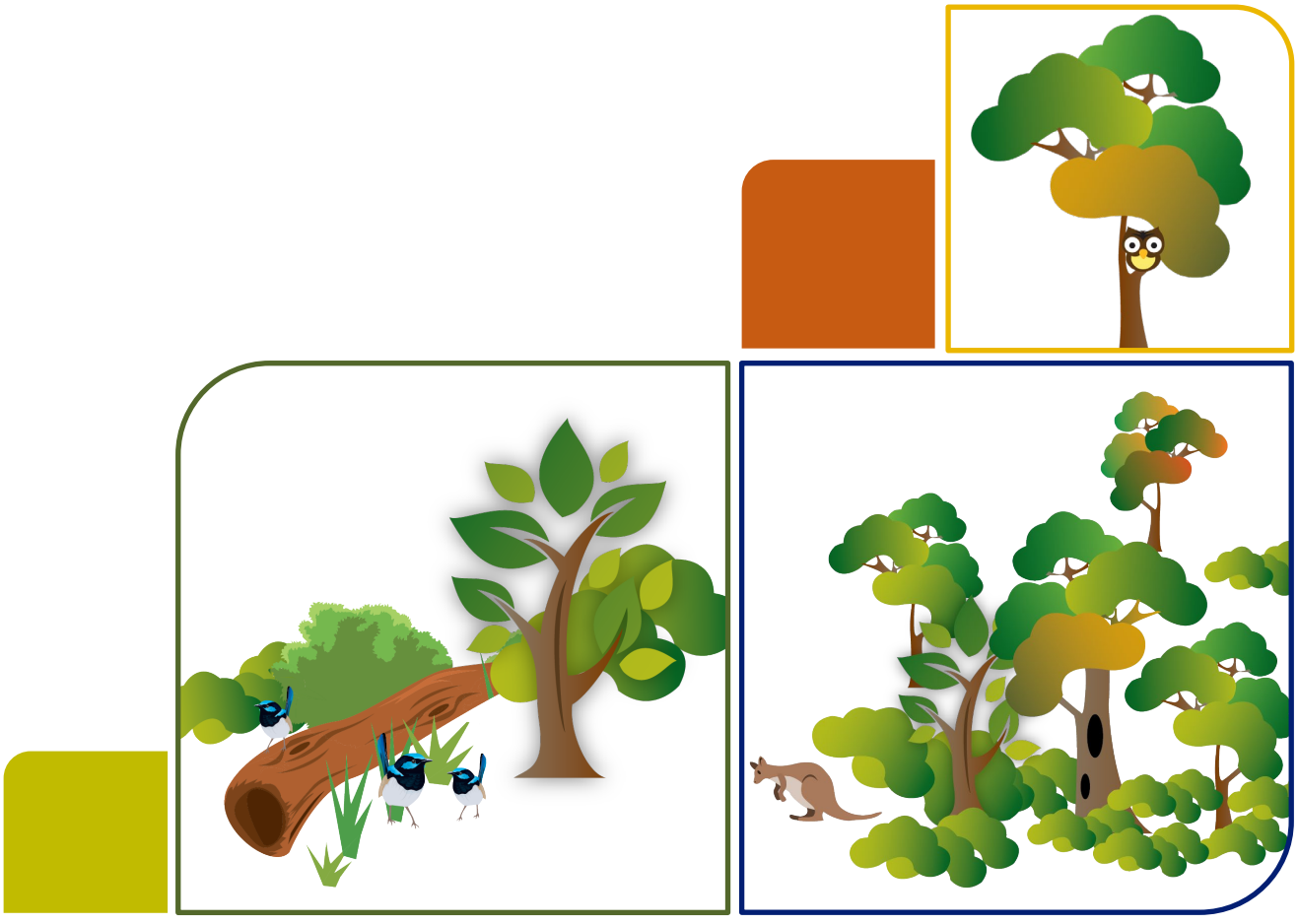
Cardinia Shire Council

Biolink Plan 2023 – 33

December 2021



Prepared by:

Cardinia Shire Council
Environment and Heritage Unit
in association with Eco Logical Australia Pty Ltd

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ABN: 32 210 906 807
20 Siding Avenue, Officer

PO Box 7, Pakenham Vic 3810
(DX 81006)

Phone: 1300 787 624
Email: mail@cardinia.vic.gov.au
Web: cardinia.vic.gov.au

Contents

List of figures

List of tables

Definitions

Term	Definition
Asset protection zone	An area around properties and infrastructure where fuel is intensively managed to provide localised protection to reduce radiant heat and ember attack on life and property in the event of a bushfire.
Barrier	Fence, vegetation or other landcover prevents animal movement.
Biolink corridor	A set of linkages through the landscape joining two core habitat nodes; considered to be critical to the maintenance of landscape connectivity for a range of animal types.
Biolink corridor number	Each of the 107 priority and future biolink corridors have been given an individual number for ease of identification.
Biolink interactive map	The interactive map enables 22 different mapping features to be viewed to support biolink conservation management actions. The web address is https://arcg.is/1fjiaK0
Biolink landscape area number	The biolink corridors have been grouped into 16 separate landscape areas
Biolink node	A cluster of patches representing a critical node within the landscape; considered to be crucial to supporting biodiversity and maintaining landscape connectivity for a broad range of animal types.
Component	A group of patches that are linked to each other but isolated from other components (also made of groups of patches).
Connectivity network	A network of interconnecting habitat patches and linkages/corridors.
Connectivity study	An analysis of the ecological connectivity across Cardinia Shire's landscape for terrestrial (land-based) fauna species. Use the GAP-CLoSR modelling framework.
Conservation corridor	Priority area to implement a limited suite of conservation works to enhance connectivity for species. Large scale revegetation to extend habitat is excluded from conservation corridors to ensure there is no increase in bushfire risk.
Core area	An area used by a species for breeding and obtaining other resources, which is different from its surroundings. The minimum size of a core area is defined as an area of habitat of sufficient size and structure to support a population of the focus species
Dispersal guild	A group of animals that share similar habitat and movement behaviour. Dispersal behaviours include the concepts of gap-crossing and inter-patch distance thresholds (Lechner et al. 2015).
Ecological vegetation division (EVD)	A native vegetation classification unit based on grouping multiple ecological vegetarian class (EVC) units that share similar ecological responses and relationships (including fire responses). There are 32 EVDs (Cheal. 2010).
Fauna	Animals.
Flora	Plants.

Term	Definition
Focal species	A species of relevance to the study area that is representative of a dispersal guild. This species is used as the basis to create modelled habitats.
Functional connectivity	The degree to which plants and animals successfully spread through the landscape, taking into consideration both the structural configuration of habitat (i.e. the nature of patches and structural connectivity elements) and the ecological requirements of the species in question.
Future biolink node or corridor	Nodes and corridors defined as 'future' are to be prioritised after works in priority nodes and corridors have been actioned.
Gap-crossing distance threshold	Maximum (average) distance an animal will move between two structural connectivity elements.
Habitat connectivity	The degree to which the landscape assists or impedes the movement of animals between habitat patches. Maximising connectivity is often an objective of conservation planning.
Habitat patch	An area used by a species for breeding and obtaining other resources, which is different from its surroundings. The minimum size of a habitat patch is defined as an area of habitat of sufficient size and structure to support a population of the focal species. Interchangeable term with 'node' in graph theory.
Horizontal connectivity	Referred to the separation distance between the different vegetation layers including the separation between understorey or overstory vegetation layers.
Indicator species	Fifteen animal species identified for the Cardinia Shire region for the purpose of informing broader conservation planning. Focal species used in the connectivity study were selected from these species.
Indigenous plants	Plants that occur naturally in a local area and have adapted to the climate and soil type of the area. They provide habitat, shelter and food for wildlife.
Interpatch-crossing distance threshold	The maximum distance that animals will move between patches provided there are sufficient structural connectivity elements present to meet the gap-crossing threshold.
Linkage (least-cost path)	The shortest pathway between two patches of habitat as a function of land cover resistance. Can indicate movement pathways or corridors for fauna (current or future) facilitated by structural connectivity elements and environments through which animals can move more easily (e.g. fewer barriers). Equivalent to a wildlife corridor.
Nationally significant	A matter of national environmental significance (MNES) listed as critically endangered, endangered or vulnerable under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.
Native plants	Plants naturally found in Australia, but won't necessarily grow well in a local area as they may be acclimatised to different rainfall and climate, i.e. a plant that grows well in north Queensland with a tropical climate will struggle to thrive in the cooler and drier climate of Victoria
Priority biolink node or corridor	Nodes and corridors defined as priority are the most important for conservation investment and are to be prioritised first
Resistance	A value assigned to each land cover type in a landscape that reflects the ecological costs for animals to move through it. Also, sometimes referred to as dispersal cost. High resistance means high dispersal costs.

Term	Definition
Rapid habitat assessment	A process of assessing habitat quality for vegetation in a cost-effective manner for comparative monitoring purposes
Riparian corridor	A unique plant community consisting of the vegetation growing near a river, stream, lake or other natural body of water.
State significant	Listed as critically endangered, endangered or vulnerable in Victoria on a Department of Environment, Land, Water and Planning Advisory List *(Department of Sustainability and Environment 2009; Department of Sustainability and Environment 2013; Department of Environment and Primary Industries 2014a).* Listed as threatened under the *Victorian Flora and Fauna Guarantee Act 1988*.
Stepping-stone	A patch of vegetation that is too small for a species to sustainably survive over a long-time frame but can provide habitat to enable species to move through the landscape to a distant core area or habitat patch.
Structural connectivity elements	Fine-scale landscape features facilitating movement and dispersal (e.g. trees, shrub cover, dense grass cover, rocks) and acting as 'stepping-stones' for species to move between habitat patches across areas of non-habitat.
Study area	The area used for the connectivity study i.e. Cardinia Shire Council local government area.
Terrestrial corridor	A plant community based on land located away from waterways
Terrestrial fauna	Animals living on land or using land for all or part of their lives
Vertical vegetation connectivity	Referred to the separation distance between vegetation. Vegetation that is physically separated could be the tree canopy, which is not touching, or understorey or ground storey species where plants are 'clumped' and don't form continuous corridors.

Abbreviations

Abbreviation	Definition
CFA	Country Fire Authority
DAWE	The Australian Government Department of Agriculture, Water and the Environment.
DELWP	The Victorian Government Department of Environment, Land Water and Planning.
EE Act	*Environment Effects Act 1978*. Victorian legislation that requires the environmental effects of certain works to be assessed, and for other purposes.
ELA	Eco Logical Australia Pty Ltd.
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*. Key piece of national legislation to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places.
EVC	Ecological Vegetation Class.
EVD	Ecological vegetation division
FFG Act	*Flora and Fauna Guarantee Act 1988*. Key piece of Victorian legislation for the conservation of threatened species and communities and for the management of potentially threatening processes.
GAP CLoSR	General approach to planning connectivity from local scales to regional framework.
MNES	Matter of National Environmental Significance as defined under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.
MBMS	Metropolitan Bushfire Management Strategy
MFMPC	Municipal Fire Management Planning Committee
NDVI	Normalised difference vegetation index.
NIR	Near infrared.
NVIM	Native Vegetation Information Management system.
OBIA	Object-based image analysis.
PBC	Potential biolink corridors
PMST	Protected Matters Search Tool.
RCS	Regional Catchment Strategy
VBA	Victorian Biodiversity Atlas.
VROTS	Vulnerable, rare or threatened species listed on the Department of Environment, Land, Water and Planning's Advisory Lists, including: Rare or Threatened Plants 2014; Threatened Vertebrate Fauna 2013; and Threatened Invertebrate Fauna 2009.

1 Executive summary

The Cardinia Shire Biolink Plan vision is to retain and enhance biodiversity in Cardinia Shire, and influence the broader region, through the protection and creation of effective biolink corridors that are safe to people and property across the landscape and along its waterways.

As the shire's population continues to grow, so too do the urban centres and agricultural systems required to support them. This changing land use inevitably leads to habitat loss and fragmentation, reducing connectivity of animal and plant populations and impairing essential ecological processes such as pollination, distribution of animals, re-colonisation, and migration. The result is that biodiversity is often limited to small, isolated habitat pockets which are vulnerable to a range of environmental threats such as pests, diseases, fire and climate change, and unable to support viable, long-term populations.

One method of mitigating the threat to remaining populations is through the protection and restoration of ecological connectivity - allowing species to move through the landscape and utilise as many of the remaining habitat elements as possible. These 'biolink corridors' are recognised as critical for addressing the impacts of habitat fragmentation and more intensive land use.

This plan presents the guiding principles for the design and establishment of voluntary environmental corridors. It provides a transparent framework to help direct investment in conservation management and builds an understanding of how to enable species to move throughout the landscape efficiently and effectively. The plan will help to coordinate organisations and communities so that priorities can individually and collectively contribute to the enhancement of Cardinia Shire's biodiversity.

In 2019, Council adopted the *Biodiversity Conservation Strategy 2019–29* to guide the restoration and management of the shire's natural environment over a 10-year period. A key goal of the plan is to map biolink corridors to enhance biodiversity connectivity across the region. As a result, Council has committed to the development of a biolink plan to provide long-term strategic direction for environmental conservation works. To assist Council in preparing the Plan, Eco Logical Australia (in collaboration with the University of Nottingham) were engaged to undertake the connectivity study and prepare the strategic corridor priorities.

This plan will also support Council's obligation to more than 4 legislative acts that direct Council as the land manager to protect native plants and animals in Council's natural resource areas against threats that contribute to species decline (Cardinia Shire's *Biodiversity Conservation Strategy 2019–29*).

Establishing and enhancing vegetation corridors can include a variety of actions from weed and pest animal control, through to protection fencing, revegetation and ecological burning. Some tasks can mitigate fire hazard while others may increase fire intensity. The plan identifies that prior to the implementation of biolinks at a landscape scale, a collaborative process with the Municipal Fire Prevention Planning Committee and, where relevant, utility managers and the community, is undertaken to achieve multiple outcomes of community safety, in highly productive landscapes that supports a sustainable natural environment.

This plan will inform conservation planning and on ground actions relating to:

- internal Council expenditure and allocation of priority project areas
- priority areas for collaboration with government departments and organisations such as but not limited to Parks Victoria, Melbourne Water, CFA, Western Port Biosphere and Trust for Nature
- community group projects with groups such as the Cardinia Environment Coalition, friends groups and Landcare networks
- providing a focus for external grant applications
- property scale local residential plans.

The plan includes 15 fauna indicator species. Three of these species including the greater glider (low mobility), eastern yellow robin (moderate mobility), and southern brown bandicoot (high mobility) were selected as focal species. Habitat connectivity modelling was completed for these three dispersal guilds all of which exhibited significant differences in their responses to the shire's landscape. The connectivity study area comprises Cardinia Shire Council municipal boundary.

To provide an overview of connectivity across the landscape for all land-based species, data from the various connectivity scenarios has been compiled, with existing and potential biolink corridors and nodes being identified.

For all species, the landscape was relatively well connected in the north, with habitat centred on Bunyip State Park in the east and Cardinia Reservoir in the west. Connectivity between these areas was limited to several narrow corridors. For less mobile species these corridors were restricted to a single, central link through Pakenham Upper and RJ Chambers Flora and Fauna Reserve. Multiple smaller corridors were identified linking out-lying habitat areas to the north and south of Cardinia Reservoir and south of Bunyip State Park.

Within the urban growth area, the patches and linkages were largely restricted to Cardinia Creek and Toomuc Creek waterways. However, modelling indicated these corridors provided limited connectivity for all species except those most tolerant of heavily urbanised landscapes.

In the south, core habitat and connectivity elements were sparse, being associated primarily with scrub along drainage lines, roadsides and property boundaries. Relatively large woodland patches in the southernmost part of the shire around Lang Lang and the coastal environments of Western Port supported limited connectivity in their respective locations.

A set of connectivity priorities has been developed to 'protect and enhance' existing habitat and biolink corridors and connect currently isolated habitats through the creation of new biolink corridors. Measures to further 'engage and educate' stakeholders based on existing activities and the suite of indicator species have been identified. Regional priorities will be supported through actions identified in the biolink action plan. Local priorities for each biolink corridor are provided in the report and are available on the Biolink Plan interactive map.

The action plan firstly defines specifications for corridor design through collaboration with fire authorities. The action plan identifies a process of fire behaviour modelling to demonstrate there is no increased risk to people and property because of the biolink corridors.

2 Introduction

The indigenous plants and animals of the shire have an intrinsic right to exist. Therefore, all public and private land managers are custodians of the shire's natural environment and the biodiversity it supports. The protection of this natural environment provides many benefits, including a sense of identity and improved quality of life for the local community, economic benefits such as healthy waterways and protection of land, mitigation of risks associated with climate change and ensuring the intrinsic value of nature can be appreciated for generations to come.

Council has a legal, ethical and social responsibility for the management and protection of biodiversity in the shire. It achieves this through developing plans and strategies, regulating land use, and investing in conservation and community programs (Cardinia Shire Council 2019).

As human populations continue to grow, so too do the urban centres and agricultural systems required to support them. This changing land-use inevitably leads to habitat loss and fragmentation, reducing connectivity of animal and plant populations and impairing essential ecological processes such as pollination, dispersal, re-colonisation, and gene flow (Fischer and Lindenmayer 2007, Saunders et al. 1991). The result is that biodiversity is often limited to small, isolated habitat elements which are vulnerable to a range of environmental threats such as pests, diseases, fire and climate change, and unable to support viable, long-term populations.

Despite the challenges, many modified landscapes contain critical populations of threatened species or communities; such is the case in Cardinia Shire with the southern brown bandicoot (*Isoodon obesulus*). The restoration, preservation and enhancement of biodiversity within modified landscapes therefore becomes increasingly important, and in turn poses a significant challenge to conservation management (Seto et al. 2012).

The risk of bushfire threat to people and property is of principal importance to Council and the community. The existence of connected vegetation and its proximity to townships represents a potential risk which is likely to increase as the impacts of climate change are realised. This presents a challenge to land managers while also presenting an opportunity to collaborate with fire authorities, government stakeholders and the community to draw on a wide range of management techniques that can achieve the multiple outcomes of safe communities in productive agricultural landscapes while supporting a sustainable natural environment.

Management of the landscape scale bushfire threat will be achieved in the Biolink Plan through the following initiatives including:

- excluding biolink corridor initiatives from all rural townships except for 9 corridors located along significant waterways
- identifying biolink corridor setbacks of 150 metres from buildings
- incorporating DELWP bushfire risk modelling into biolink corridor design
- collaborating with the Municipal Fire Prevention Management Committee to guide the design of each landscape scale biolink corridor.

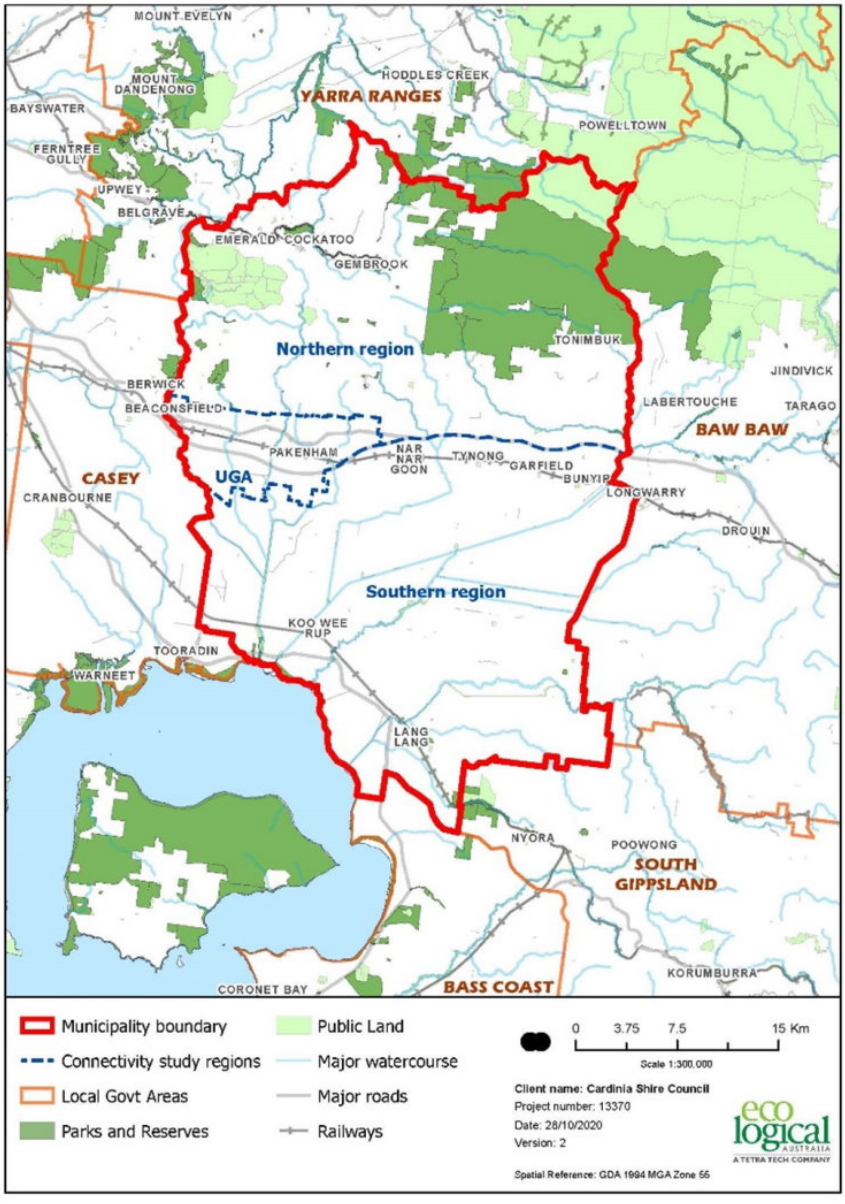
One method of mitigating the threat to Cardinia Shire's remaining biodiversity is through protecting and restoring ecological connectivity - allowing species to move through the landscape and utilise as many of the remaining habitat elements as possible. These 'biolink corridors' are recognised as critical for addressing the impacts of habitat fragmentation and more intensive land use (Bierwagen 2007, Minor and Urban 2008). Complementing the biolink corridors concept are the 'biolink nodes'. These areas represent large clusters of highly connected habitat which can support a diverse range of flora and fauna. Identifying, protecting and creating biolink corridors and nodes is critical to the preservation of local and regional biodiversity.

Conservation management actions to protect and enhance biodiversity can be highly varied and can include:

- pest plant control
- pest animal control
- protection fencing - i.e., fencing remnant vegetation from grazing
- revegetation
- artificial habitat creation - habitat boxes, shelter refuges, frog ponds, amelioration of roadside barriers
- stimulating natural ecological processes - ecological burning, altering hydrological water levels
- community awareness programs.

The connectivity study area bounded by Cardinia Shire Council municipal boundary. For the connectivity analysis, the shire has been broken into three regions roughly aligning with the highlands southern fall bioregion in the north, the Gippsland plain bioregion in the south, and the urban growth area around Pakenham, as shown in Figure 1.

Figure 1. Cardinia Shire Council municipality boundary



Modelling was completed for 3 dispersal guilds, using greater glider (low mobility), eastern yellow robin (moderate mobility), and southern brown bandicoot (high mobility) as the focal species. All exhibited significant differences in their responses to the shire's landscape.

2.1 Biodiversity Conservation Strategy (2019 –29)

In 2019, Council's *Biodiversity Conservation Strategy 2019-29* was developed to guide the restoration and management of the shire's natural environment over the next 10 years and beyond. A key goal of the plan is to map biolink corridors to enhance biodiversity connectivity across the region.

The strategy was developed using data collected in 2017 by Council in a review and audit of biodiversity health and from scientific reporting of the threats to biodiversity in the shire.

The vision of the strategy is *Cardinia Shire's natural environment is protected, valued and enhanced in partnership with the community to improve our quality of life*. To attain this vision, 4 key goals have been identified and separated into the themes protect, enhance, connect and engage and educate:

- Goal 1: protect – achieve a net gain of the overall extent and condition of habitat across land and waterway environments
- Goal 2: enhance – the quantity and quality of indigenous flora and fauna is improved on private and public land
- Goal 3: connect – Council has mapped biolink corridors that will enhance biodiversity connectivity across the region
- Goal 4: engage and education – the number of community members actively participating in natural environment programs has increased.

Improving connectivity has been identified as a key goal of the *Biodiversity Conservation Strategy*, recognising the restoration of ecological connectivity will enable native flora and fauna to move through the landscape and increase genetic diversity among breeding populations ensuring the long-term viability of native species. To achieve this goal, this plan identifies future ecological connectivity corridors that will improve water quality through the protection and enhancement of rural waterways, enhancing the environmental condition of Western Port and Yarra River catchments and community connections with the natural environment.

2.2 Climate change

Climate change is one of the greatest long-term threats for our time. 'The adverse impacts of climate change on biodiversity are projected to increase with increasing warming' (Services, 2019). Conservation planning and management therefore needs to ensure the future landscape is resilient to a drying climate that could otherwise threaten the survivability of our native flora and fauna. This requires careful species selection such as the use of species tolerant of drier conditions and novel approaches to species selection to ensure that fauna habitat is established but is resilient. This may include use of native non-indigenous species for specific locations.

The most vulnerable ecosystems include coastal ecosystems, forests, fragmented terrestrial ecosystems and areas vulnerable to fire or low freshwater availability. Species that could become endangered or extinct include those living near the upper limit of their temperature range, those with constrained climatic niches, and those that cannot migrate to new habitats due to habitat fragmentation or lack of suitable alternatives. Addressing the impacts of climate change on biodiversity will require a long-term effort and new ways of thinking, with the protection and improvement of connectivity a key step. This plan will respond to climate risks to biodiversity in 4 priority themes which are detailed further in Section 10.3 . These themes include:

- improving our scientific understanding
- identifying strategic biodiversity priorities and corridors
- protecting strategic biodiversity habitats
- adaptation planning and management opportunities.

3 Vision and goals

3.1 Vision

The vision for the Biolink Plan has been designed to encapsulate not only the need to protect and maintain the natural environment for intrinsic purposes, but to also garner support from a range of public and private stakeholders, through providing information that will assist and facilitate these organisations, groups and individuals to achieve better conservation outcomes.

Retain and enhance biodiversity in Cardinia Shire, and the broader region, through the protection and creation of effective biolink corridors across the landscape and waterways that are safe to people and property.

3.2 Goals

This plan's goals have been divided into 4 distinct themes to maintain consistency with Council's *Biodiversity Conservation Strategy 2019–29*

1. Protect
2. Enhance
3. Connect
4. Engage and educate

Table 1. Goals and objectives

1. Protect – we achieve a net gain of the overall extent and condition of habitat across land and waterway environments which are considerate of bushfire safety to people and property	
Objective 1.1	Populations of priority threatened species are sustainable and have increased
Objective 1.2	Corridors are implemented in collaboration with Municipal Fire Prevention Planning Committee
Objective 1.3	Biolinks are carefully designed to protect people and property from increased bushfire risk
2. Enhance – the quantity and quality of indigenous flora and fauna is improved on private and public land	
Objective 2.1	Habitat quality (structural and functional) improves with focus on biolink nodes
Objective 2.2	Diversity of vegetation and habitat types is increased
Objective 2.3	Resilience in biolink corridors is increased through strengthening the quality and number of linkages (redundancy) along biolink corridors in the face of a changing climate
3. Connect – Council has mapped bio-link corridors that will enhance biodiversity connectivity across the region	
Objective 3.1	Biodiversity values are clearly mapped
4. Engage and educate – the number of community members actively participating in natural environment programs has increased	
Objective 4.1	Actively engage with Cardinia Shire's Traditional Owner groups to find collaborative opportunities in the delivery of the biolink action plan
Objective 4.2	Community participation in environmental programs that support biolink corridors has increased by 2031
Objective 4.3	Opportunities are provided for the community to connect with nature

4 Strategic context

To ensure the relevancy and feasibility of the goals and underpinning management priorities outlined in the Biolink Plan, consideration has been given to the local, regional and state context with regards to legislation, policies and initiatives, at both a strategic and on-ground level. A summary of past and present plans and programs considered in the development of this plan is provided in Appendix B.

Of relevance are Council's *Biodiversity Conservation Strategy* (discussed above) and the Healesville to Phillip Island Nature Link (HPNL) Strategic Plan. The nature link is an initiative to connect vegetation corridors from the Yarra Ranges near Healesville with Western port and the Bass Coast in the south. This will include significant planning and investment in establishing corridors through the shire, with many of the existing drains already identified as potential assets which could facilitate connectivity. The fine-scale results of the connectivity study will therefore be important for identifying existing and potential biolink nodes and biolink corridors and guiding on-ground works to achieve the objectives of the HPNL project.

This plan supports the Victorian Government's *Biodiversity 2037* strategy goals through:

- the identification of biolink assets which inform strategic management actions efficiently protect the maximum number of species
- empowering agencies and communities to work together to enhance the natural environment
- promote agencies and the community to value nature through increased interaction and connectivity in biolink biodiversity programs
- actioning environmental data capture through monitoring programs to feed into the Victorian Biodiversity Atlas.

Key state-wide aims that are supported in the plan include:

- a net gain in the overall extent and condition of habitats across terrestrial, waterway and marine environments
- no vulnerable or near-threatened species will become endangered
- all critically endangered and endangered species will have at least one option available for being conserved
- 200,000 hectares of new permanently protected areas on private land
- 200,000 hectares of revegetation in priority areas for connectivity between habitats.

The plan also supports the Port Phillip and Western Port Catchment Management Authority Regional Catchment Strategy (RCS) goals, through the direct alignment of 13 of the 15 strategy themes. Implementation of the Biolink Plan contributes to supporting the RCS goals to permanently protect 40 hectares of vegetation and revegetate 200 hectares per year.

It is proposed that the biolink corridor data will be shared onto the RCS portal to contribute to connected corridors throughout the region. The RCS web-based portal and 'prospectus page' provides collaborative opportunities to link Council's strategic environmental goals with other partner organisations in the region.

The plan supports the environmental objectives within Council's *Liveability Plan* to enhance the natural environment and increase community participation in open spaces.

Several previous studies have been undertaken within the shire or broader region with a focus on habitat connectivity and prioritisation. These include:

- *Melbourne Water Healthy Waterways Strategy* (2019)
- *Bass Coast Biodiversity Biolink Plan* (Bass Coast Shire Council 2018)
- *Western Port Biosphere Reserve Biodiversity Plan* (Chambers and Jacka 2015)
- *Latrobe Catchment Biolink Strategy* (Maclagan 2011)
- *Southern Brown Bandicoot Strategic Management Plan* (Ecology Australia 2009)

- *Biolink Project Action Plan mapping* (Cardinia Environmental Coalition 2009).

These documents have been used to inform the connectivity study through identifying broader regional priorities, including linkages to adjoining local government areas and associated biodiversity assets.

Other resources such as Department of Environment, Land, Water and Planning (DELWP)'s Nature Print products, including the Strategic Management Prospects tool, and species records contained in the Victorian Biodiversity Atlas have been used to inform habitat specifications for individual species and priorities in the shire's context, as well as reviewing and validating the results of the connectivity analysis.

5 Cardinia Shire's cultural heritage and biodiversity

5.1 Cultural heritage

The Yarra and Western Port catchments are part of the traditional country of the Mayone buluk and Yallock balug clans of the Bunurong/Boonwurrung[1] people and the Bulug willam clan of the Woi Wurrung (Canning et al. 2010). Each have strong connections to the land through their ancestral history and spiritual relationships, as custodians of the land for over 40,000 years.

The Boonwurrung/Bunurong and the Woi Wurrung (Wurundjeri) people are part of the broader alliance of the Kulin Nation which also includes the Watha Wurrung, the Djaja Wurrung and the Taung Wurrung peoples, who share a common language (Rhodes et al. 2004).

The Traditional Owner land use practices have shaped the natural environment, creating the diverse legacy of native plants and animals now found in Cardinia Shire. Traditional Owner knowledge and experience is important to inform future actions within the Biolink Plan.

5.2 Regional context

Cardinia Shire is located on the fringe of metropolitan Melbourne, approximately 70 km to the south-east of the central business district and is comprised of 128,244 hectares of primarily peri-urban and rural lands, and state forests and reserves. Within the shire, urban growth areas and townships equate for 8% of the total land use, with the remaining 92% rural (Cardinia Shire Council 2019). The townships of Beaconsfield, Bunyip, Garfield, Koo Wee Rup, Lang Lang, Officer and Pakenham form part of the urban growth boundary within the shire (VicPlan 2020).

In the north, the highlands southern fall bioregion forms part of the southerly aspect of the Great Dividing Range and is characterised by a mixture of large state forests, smaller reserves and cleared plains and lower slopes occupied by a mixture of pastural and horticultural lands, and smaller peri-urban and bush blocks. Native vegetation is comprised primarily of medium to tall eucalypt woodlands and forests, supporting diverse mid and ground layers of shrubs, ferns, graminoids and herbs on a range of geologies and elevations (Department of Environment, Land, Water and Planning (DELWP) 2020).

The Gippsland plain bioregion covers more than half of the shire to the south and is characterised by flat to gently undulating terrain on a range of soil types. This area was previously a vast swampland known as 'The Great Swamp' which extended beyond the boundaries of the shire to the west and east. Draining of the swamp commenced in the 1870s with the creation of numerous large and small channels through the plain. The area is now largely pastoral, with some areas of intensive 'market gardens' along the main channels. Native vegetation across the southern region is largely restricted to saltmarsh and mangrove communities along the coastline and small fragments of swamp scrubs and woodlands along drainage lines and roadsides (DELWP 2020 and Cardinia Shire Council 2019).

Extending along 17 kms of the shire's western coastline is the Ramsar and *Environment Protection and Biodiversity Conservation Act* listed Western Port Bay which comprises deep channels, seagrass flats, intertidal mudflats, mangrove thickets and saltmarsh vegetation (Commonwealth of Australia 2017). It supports a diverse range of flora and fauna, including numerous migratory waterbirds listed under international migratory bird conservation agreements (Kellogg Brown & Root 2010).

In the north-east of the shire, the 166 km^2 Bunyip State Park represents a key area of biodiversity, comprising a variety of habitat types ranging from heathland swamps to Mountain Ash forest (Parks Victoria 2020).

[1] There are many spellings used in describing these Traditional Owners. Cardinia Shire Council recognises both the Bunurong and Boonwurrung spellings, as requested by Traditional Owner representative groups.

To the north-west, Cardinia Reservoir and surrounding bushland reserves dominates the landscape. The reservoir is a major supplier of water to Melbourne, and is surrounded by extensive woodlands and forests, as well as many smaller reserves and parks.

Approximately 80 bushland reserves, 950 kms of roadside vegetation (ranging from low to very high quality) and 19 significant waterways and tributaries make up the remaining important habitat within Cardinia Shire (Cardinia Shire Council 2019).

5.3 Vegetation and habitat

5.3.1 Native forests

Native forest habitats in the shire consist predominantly of medium to tall Eucalyptus canopies with a cover of 30-40 percent, and a variable and diverse shrubby midstorey of species such as *Acacia, Oleria*, *Leptospermum* and *Correa*. The understorey is a mixture of herbs and grasses, with ferns and tree ferns common in wetter habitats.

These forests are situated on the higher elevation plains to the north of the shire, in the Highlands Southern Fall bioregion, and within riparian corridors. Native forests are the least impacted native vegetation type in Cardinia Shire, with large areas of remnant forest found in the north-east in the Bunyip State park.

Common forest ecological vegetation classes (EVCs) within the shire include herb-rich foothill forest (23), shrubby foothill forest (45), valley grassy forest (47), lowland forest (16), cool temperate rainforest (31), warm temperate rainforest (32), riparian forest (18), damp forest (29) and wet forest (30).

5.3.2 Native woodlands

Native woodland habitats are comprised of vegetation with a canopy cover of 5-15% and Eucalypts as the dominant tree species. The understorey is generally diverse, with grasses, herbs or heathy species (*Leucopogon, Epacris*) more or less dominant depending on the aspect and geology. A shrub layer is sometimes present, with *Acacia, Kunzea* and *Leptospermum* common.

Woodlands occur on the lower slopes of the highlands southern fall bioregion within the shire. Most remnant areas of woodland occur in the peri-urban or rural areas north of Pakenham. Large areas of remnant damp heathy woodland also occur on slopes of a southerly aspect in the Bunyip State Park and in the far south-east of the shire around Lang Lang. Swampy and riparian woodland communities are also commonly along natural watercourses on the lower slopes and plains of the shire.

Common woodland EVCs within the shire include damp heathy woodland (793), heathy woodland (48), damp sands herb-rich woodland (3), grassy woodland (175), swampy riparian woodland (83) and swampy woodland (937). Several ‘forest’ EVCs, including grassy dry forest (22), grassy forest (128) and heathy dry forest (20), have been classified as woodlands for the purpose of this study due to their functional and structural habitat characteristics.

5.3.3 Native grasslands

Native grassland habitats are comprised of vegetation with sparse or no cover (<5%) of trees or shrubs and at least 25% cover of native ground layer grass species (e.g. *Rytidosperma* or *Themeda*). In Cardinia Shire, these communities have been largely cleared, with approximately 20 hectares remaining around Pakenham and Cardinia Creek. Plains grassland (132) is the only grassland EVC within the shire.

5.3.4 Native scrubs

Native scrubs are associated with rivers, creeks, swamps and drainage lines, on poorly drained and seasonally waterlogged soils. The dominant layer in these communities is an often-tall shrub-layer of *Leptospermum* and/or Melaleuca, which sometimes forms a dense thicket. The understorey can be sparse or host a diverse herb, grass or fern layer. Emergent Eucalypts tolerant of wet conditions, such as swamp gum (*Eucalyptus ovata*) are common.

Native scrubs and swampy woodlands are found across both the Gippsland plain and highlands southern fall bioregions in the shire, primarily in association with drainage lines. In the south, native scrubs are often present as recolonising vegetation along roadside drains, channel embankments and unmanaged land.

Common scrub EVCs within the shire include swamp scrub (53), riparian scrub (191), riparian thicket (59), berm grassy shrubland (311), coastal headland scrub (161), swampy riparian complex (126) and blackthorn scrub (27).

5.3.5 Native coastal saltmarsh, grasslands and mangroves

The coastal interface of the shire is dominated by coastal saltmarsh. This vegetation type consists of a range of succulent, salt-tolerant herbs (e.g. *Disphyma, Sarcocornia*) and low shrub species, with rushes and sedges occasionally occurring. Adjacent to or in mosaic with this vegetation type are shrublands dominated by white mangrove (*Avicennia marina ssp. australasica*), and estuarine grasslands where a more diverse grass layer occurs amongst the salt-tolerant herbs and shrubs.

These vegetation types occur in the coastal and estuarine environment on estuarine tidal flats in saline environments. In Cardinia Shire, these are found on the Gippsland plain where it meets Western Port, and inland along the estuaries of the Bunyip River, Cardinia Creek, Deep Creek and Toomuc Creek.

Common coastal EVCs within the shire include coastal saltmarsh (9), coastal saltmarsh/mangrove shrubland mosaic (302), mangrove shrubland (140) and estuarine flats grassland (914).

5.4 Biodiversity

5.4.1 Flora (plants)

Over 1,800 plant species (from the family's plantae and fungi) have been recorded within the shire (DELWP 2019) (Table 2). Flowering plants (*angiosperms*) dominated flora records and species diversity followed by ferns and fern allies. *Gymnosperms* (pines, cypress), mosses and lichen (*bryophytes*), fungi and algae were also present but in much smaller numbers.

Table 2. Flora and fungi species diversity and composition in Cardinia Shire (excluding animalia)

Flora class (taxon)	All flora	Indigenous flora
Algae	1	1
Angiosperms	1802	1218
Mosses and liverworts	90	88
Conifers, cycads and allies	9	1
Ferns and allies	69	68
Fungi	2	2

Within the flowering plants recorded, *dicotyledons* (dicots) were more diverse than *monocotyledons* (monocots) (Table 3). Approximately two-thirds (64%) of dicot species are indigenous to the shire and three-quarters (74%) of monocots. Within monocots, grasses are the most diverse group with 213 species, 113 of which are indigenous. A very high diversity of orchid flora has been recorded in the shire with 133 species, all indigenous. In Cardinia Shire, 86 indigenous sedges, 51 indigenous rushes and 79 indigenous lilies and other small flowering grasses have also been recorded.

Table 3. Flora and fungi species diversity and composition in Cardinia Shire – flowering plants (angiosperms)

Flora class (taxon)	All flora	Indigenous flora
Dicots	1177	756
Monocots	625	462
Monocots – grasses	213	113
Monocots – orchids	133	133
Monocots – rushes	60	51
Monocots – sedges	92	86
Monocots – lilies/other	127	79

The Victorian Biodiversity Atlas contains records for 102 threatened flora species in the shire. Species with the greatest number of records were Hairpin Banksia *(Banksia spinulosa var. cunninghamii*) (467 records) and *Green Scentbark (Eucalyptus fulgens)* (197 records) with 28 of the remaining species having ten or more records.

Most of the flora diversity in the shire is located in the northern region where vegetation is more intact, and a diverse array of species is reflected throughout the history of data records. In the south of the shire, records are concentrated around areas of retained vegetation associated with small reserves, drains, roadsides and rail lines.

5.4.2 Fauna

Table 4 and Table 5 show that over 450 fauna species have been recorded in the shire (DELWP 2019). Based on species records, birds represent over half the diversity (62%), followed by mammals (10%) and fish (6%). All other groups account for the remaining 22% of species diversity. Frogs were the least diverse group of vertebrates recorded. Indigenous fauna accounted for 93% of species recorded in the shire.

Table 4. Fauna species diversity and composition in Cardinia Shire – vertebrate

Fauna class (taxon)	All fauna	Indigenous flora
Bird	326	312
Fish	33	24
Frog	20	20
Mammal	39	28
Reptile	29	29

Table 5. Fauna species diversity and composition in Cardinia Shire – invertebrate

Fauna class (taxon)	All fauna	Indigenous flora
Crustacean	14	14
Insect	4	4

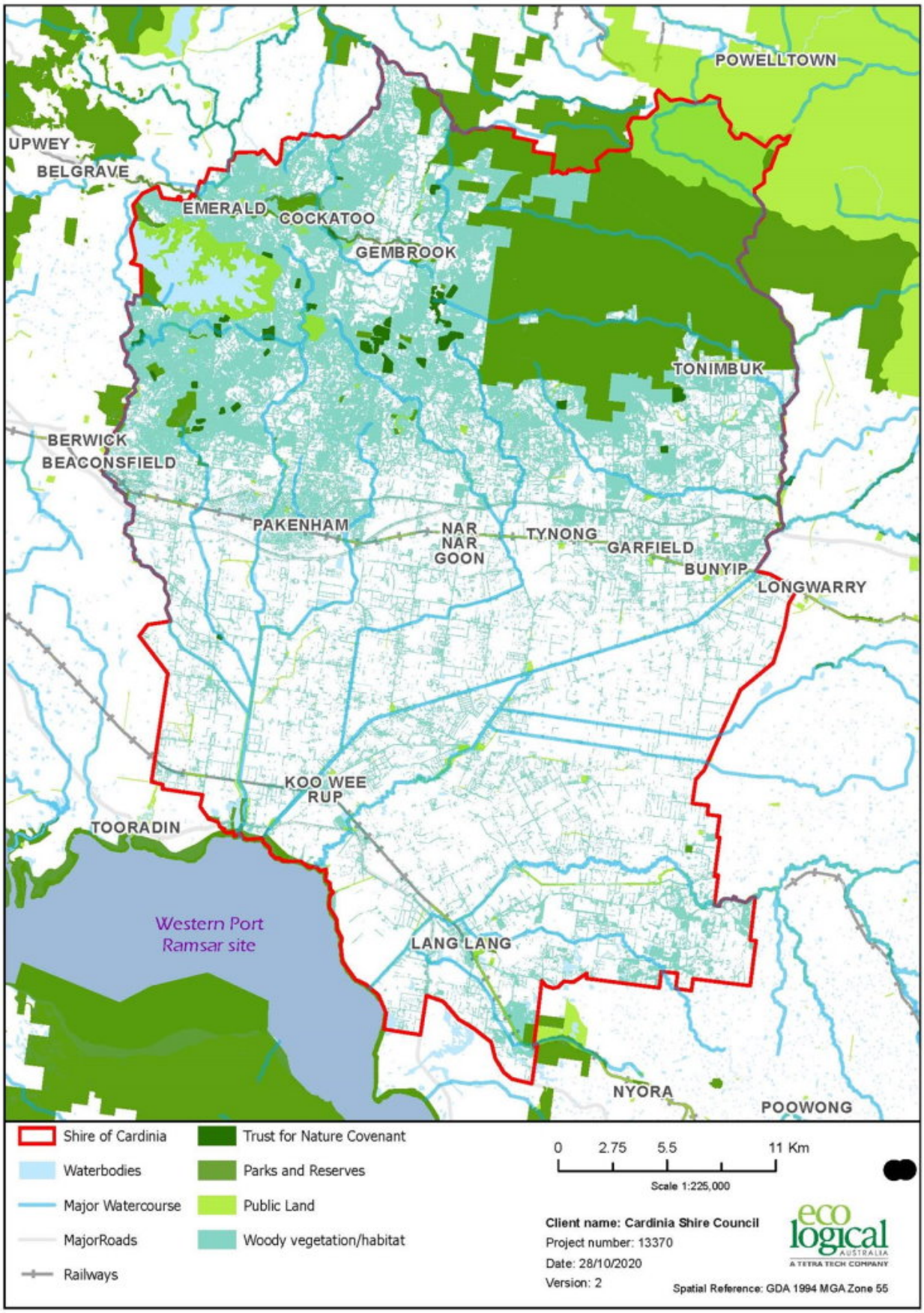
One hundred and fifty-seven state or nationally threatened species have been recorded in the shire (DELWP 2019), the majority of which are birds. A further 82 species are listed as migratory under the *EPBC Act* and protected under international conventions. Forty-eight of the 157 threatened species have been observed in the last ten years, and of these, less than half are represented by more than ten records. Threatened species were commonly associated with forest, riparian and aquatic habitats, with migratory species focused on coastal habitats. Records of southern brown bandicoot were notably high, with 340 records from within the past 10 years in the south of the shire.

Fauna records were more well-distributed across Cardinia Shire than flora records, with many records still within the northern highlands area where the vegetation has remained more intact, but a large number also centred around the towns of Pakenham, Koo Wee Rup and Lang Lang. Fauna is also frequently recorded along the coastline, rivers and creeks that cross the southern area.

5.5 Biodiversity assets

Biodiversity assets within the shire have been well studied with many of the key biodiversity areas and corridors having been broadly identified. The extent of natural vegetation, areas of public land that contain biodiversity and land protected by Trust for Nature covenants are defined in Figure 2. While the importance of these assets and the contribution to landscape connectivity has not been quantitatively assessed, this knowledge represents the foundation on which further connectivity studies can be conducted. Known biodiversity areas and corridors and key threats to biodiversity are presented in Appendix A.

Figure 2. Biodiversity values in Cardinia Shire



6 Indicator species

The habitat requirements and tolerance to changing land use varies considerably across the shire's different fauna groups and species. With increased urbanisation and intensification of agricultural activities expected in the future, the selection of fauna 'indicator' species has been proposed as a focal point for future conservation management, including planning, monitoring and community engagement, as well as informing the connectivity study and corridor specifications.

The fauna indicator species represent a diversity of fauna species and groups, including those from differing habitat types, lifeform groups, conservation significance, and dispersal and movement capabilities. To represent these requirements, a set of selection criteria were developed (Table 6) and used to select the final 15 species (Table 7). Subsequently, 'species standards' were developed for each indicator species and are presented in Appendix D.

Table 6. Indicator species selection criteria

Criteria	Description
Fauna group	Select a range of species representative of different faunal groups, habitat types, functional roles etc.
Conservation significance	Select species with a variety of conservation status based on listing at a local/shire, regional, state or national level.
Abundance	Select a range of species that are both rare and common within the shire.
Tolerance to disturbance / urban environments	Select a range of species so as to have both high and low tolerance to disturbance and urban settings.
Structural habitat requirements	Select species that utilise different habitat features or structures.
Range and patch size requirements	Select a range of species that represent both large and small patch size/home range requirements.
Connectivity requirements	Select a range of species with different dispersal abilities (e.g. inter-patch movement and gap crossing thresholds).
Ease and efficacy of survey	Identify some species that are easy to survey and monitor.
Opportunities for future collaboration	Select species which can be used as a focus of future engagement, education or collaboration

Table 7. Final indicator species for Cardinia Shire

Common name	Species name
Growling grass frog	*Litoria raniformis*
Powerful owl	*Ninox strenua*
Southern brown bandicoot	*Isoodon obesulus obesulus*
Platypus	*Ornithorhynchus anatinus*
Southern greater glider	*Petauroides volans*
Superb lyrebird	*Menura novaehollandiae*

Common name	Species name
Blue-tongued lizards	*Tiliqua nigrolutea and scincoides*
Eastern yellow robin	*Eopsaltria australis*
Lace monitor	*Varanus varius*
Chocolate wattled bat	*Chalinolobus morio*
Superb fairy wren	*Malurus cyaneus*
Swamp skink	*Lissolepis coventryi*
Agile antechinus	*Antechinus agilis*
Swamp wallaby	*Wallabia bicolor*
Eastern pygmy possum	*Cercartetus nanus*

Drawing from the final list of indicator species, three 'focal species' have been selected to represent dispersal guilds in the connectivity study (greater glider, eastern yellow robin and southern brown bandicoot).

7 Connectivity analysis

7.1 Approach

Connectivity can be thought of as the extent to which a landscape facilitates the movements of organisms and their gene pool. The maintenance and restoration of connections between habitat patches is designed to maximise 'functional connectivity', which is the degree to which flora and fauna move through the landscape between patches and support viable populations. Underlying this is the concept of 'structural connectivity' composed of natural features (such as trees, patches, or corridors of vegetation) which facilitate wildlife movement.

While the importance of connectivity is recognised as being critical for conservation, identifying which species have suitable connectivity, or what landscape elements contribute to connectivity remains a challenge for regional planning. Most connectivity modelling examples are either very general, whereby connectivity is applied to landscape features, or very specific, whereby connectivity is applied to a single species or multiple species modelled separately. The 'General Approach to Planning Connectivity from Local to Regional Scales' (GAP CLoSR) method combines both a species approach with a general landscape features analysis, characterising connectivity for groups of species ('dispersal guilds') based on shared dispersal and habitat characteristics. For this report, we have adapted the GAP CLoSR dispersal guild concept and modelling framework.

The processes involved in habitat connectivity modelling using the GAP CLoSR method can be broken into four key steps:

1. focal species selection and parameterisation (literature review and expert opinion)
2. landcover classification to identify habitat and gap-crossing layers (remote sensing)
3. characterise landcover resistance (remote sensing and expert opinion)
4. modelling using GAP CLoSR decision framework

Outputs of the connectivity modelling include the identification for each focal species of:

- 'core habitat' based on the minimum patch size considered viable to sustain a population
- least-cost paths ('linkages') based on the species dispersal parameters
  - i.e. gap-crossing threshold, interpatch distance, structural connectivity elements and resistance to landcover types
- a connectivity index for each patch and linkage
  - indicating the relative importance and contribution to connectivity across the entire network
- component boundaries, delineating the boundary of interconnected habitat.

Where the modelling identified clusters of highly interconnected habitat patches, these have been collectively referred to as 'biolink nodes'. The network of linkages connecting the biolink nodes are collectively referred to as 'biolink corridors'.

The connectivity study area encompasses the Cardinia Shire Council municipal boundary. For the purpose of the connectivity analysis, the shire has been broken into three regions roughly aligning with the highlands southern fall bioregion in the north, the Gippsland plain bioregion in the south, and the urban growth area around Pakenham. The Princes Highway has been used as the boundary between the north and south regions due to the change in physical landscape at this point and the resistance associated with this barrier.

A detailed description of the connectivity modelling method is provided in Appendix A.

7.2 Focal species selection

A dispersal guild approach was taken which characterises connectivity for groups of species based on shared dispersal behaviour and ecological requirements (Lechner *et al*. 2015b, Lechner *et al.* 2017). The intent is to select dispersal guilds representative of the biodiversity present within the study area and which may be limited by connectivity. Given the scope of this study provided for the

modelling of three focal species, only low and moderate mobility species have been selected as these represent guilds most effected by fragmentation, which is a key limiting factor for species in the shire. Table 8 outlines a variety of potential patch size and habitat requirements used to consider when selecting the focal species

Table 8. Mobility and habitat size used for biolink connectivity study

Mobility			Habitat size		
Dispersal guild	Gap-crossing range	Inter-patch range	Large (>10ha)	Moderate (5-9ha)	Small (<5ha)
High	>300m	>1500m	Guild A1	Guild A2	Guild A3
Moderate	75 - 300m	500-1500m	Guild B1	Guild B2	Guild B3
Low	<75m	<500m	Guild C1	Guild C2	Guild C3

Within these guilds a representative focal species was selected from the 15 indicator species identified for the Biolink Plan. Focal species were selected to ensure they:

- covered a range of habitat types and localities throughout the shire
- were suitable for use in the GAP-CLoSR modelling framework
- had dispersal thresholds and habitat parameters that could be reasonably determined based on information contained in the scientific literature and expert opinion
- have habitat associated with terrestrial woody vegetation (as this is readily and accurately identified through the remote sensing analysis).

The three focal species selected include the Greater glider, Eastern yellow robin and Southern brown bandicoot. Table 9 provides the three focal species associated connectivity parameters.

Table 9. Focal species parameters

Guild	Species	Habitat type	Connectivity elements	Min Patch Size (ha)	Gap-crossing threshold (m)	Interpatch-crossing distance (m)	Region
B2	Eastern yellow robin	Woodlands, Forests	Forests, Woodlands, Scrubs, Heathlands	5	100	900	All
B3	Southern brown bandicoot	Woodlands, Scrubs	Forests, Woodlands, Scrubs, Heathlands	3	100	1500	South
C1	Southern greater glider	Forests	Forests, Woodlands	10	75	150	North

The selection of species was limited to those with a strong association to woody-vegetation, including forests, woodlands and tall scrubs (e.g. swamp scrub). Grassland specific guilds were not considered due to the inability of the remote sensing analysis to differentiate between different types of non-woody vegetation (e.g. native grasslands from pastures or parks).

7.3 Remote sensing

7.3.1 Land covering classification

Figure 3 shows that vegetative cover in the remote sensing exercise was concentrated in the north of the shire.

Figure 3. Land classification by cover and habitat

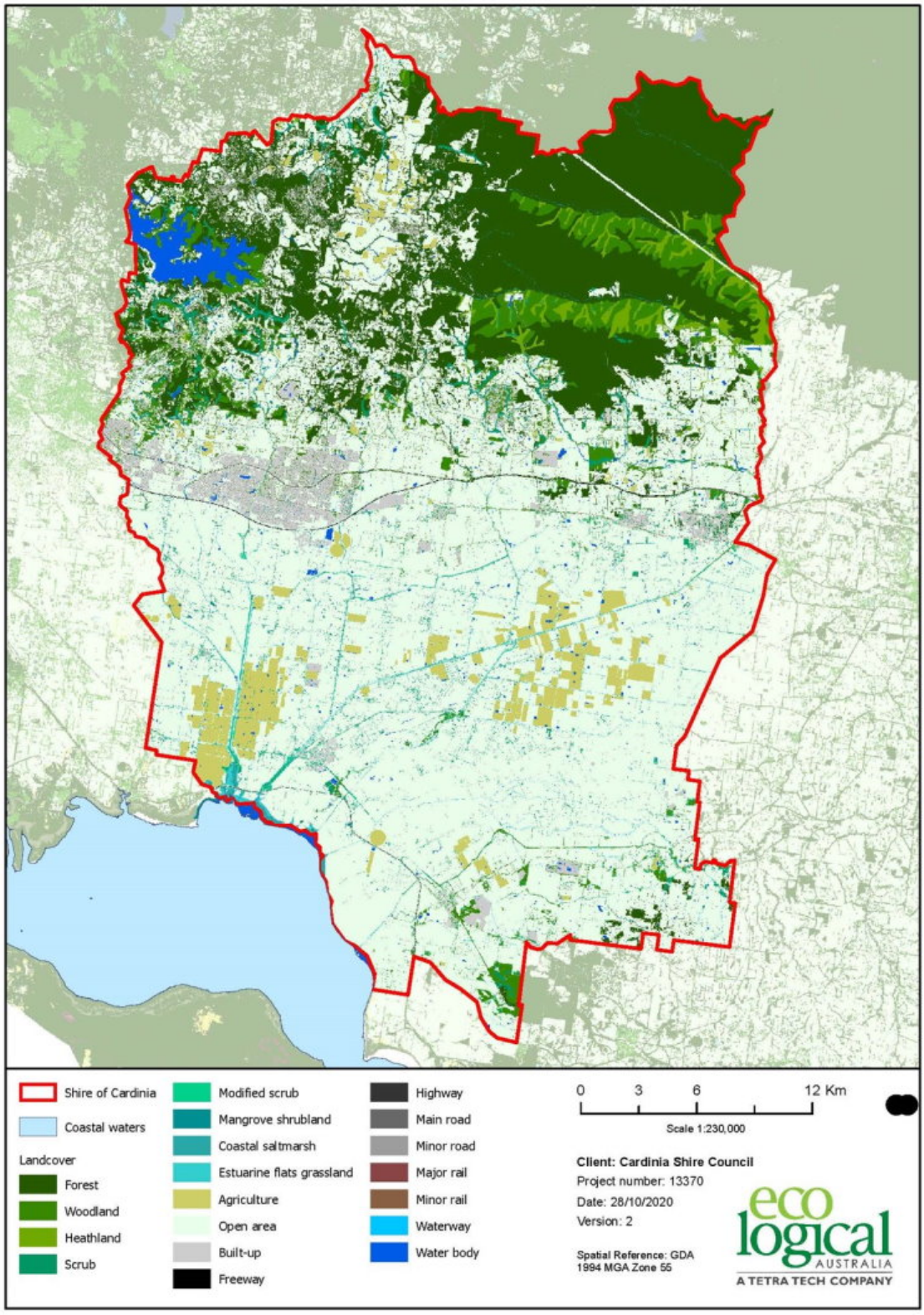


Table 10 shows the dominant landcover classification in the shire was pasture and open areas, followed by habitats comprised predominantly of forest habitat types.

Table 10. Landcover classifications and area based on remote sensing analysis

Classification	Area (ha)	Classification	Area (ha)
Terrestrial fauna habitat	43,116	Agriculture (intensive)	5,388
Forest	29,309	Built-up areas	4,528
Woodland	7,735	Freeway	122
Heathland	1,618	Highway	115
Scrub	2,807	Main road	231
Mangroves	70	Minor road	1050
Saltmarsh	194	Major rail	27
Estuarine flats	121	Minor rail	17
Modified scrub	1,262	Water body	3,401
Pasture and open areas	83,162	Waterway	740

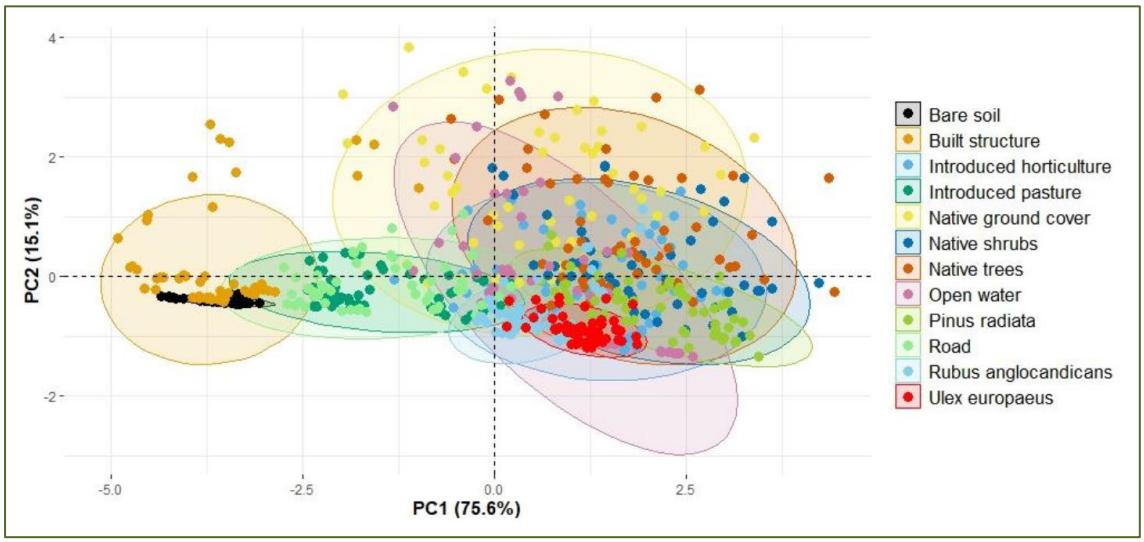
7.3.2 Spectral analysis

The vegetation analysis methodology used in this plan is called 'principle component analysis' which converts multidimensional data into linear components, as is shown in the ordination plot for all landcover classes assessed in Figure 4. The overlap in cluster boundaries represents where different land covers have similar spectral values. The results show non-vegetation classes, such as bare soil or built structures, as distinct from vegetation classes with the exception of open water. While 'introduced pasture' and 'road' share very similar spectral traits these classes have very different distributions allowing separate classification in the object-based analysis. This analysis enabled the computer modelling technology to define and create the biolink patches, nodes and corridors. The remaining vegetation classes on the right of the ordination plot show significant overlap with no discernible difference.

Further testing was undertaken with subsets of the landcover classes, with a focus on trying to separate introduced from native vegetation. The results indicated there was no distinct difference when comparing both treed vegetation of different origins (e.g. eucalyptus species with *Pinus radiata*) or understorey vegetation (e.g. pasture vs native shrubs vs weeds such as *Rubus anglocandicans*).

The preliminary analysis therefore indicates that the use of multi-spectral data alone is not enough to conduct automated mapping of weedy species. This is consistent with the literature which presents only a limited number of successful examples of species level mapping.

Figure 4. Spectral analysis to inform computer modelling of biolink assets



7.3.3 Classification accuracy

An initial assessment of land cover accuracy was undertaken on the final landcover map. Using 15 points per class, the accuracy was determined to be 91%. Importantly, the detection/classification of woody vegetation was found to be 100%.

Despite this, a current deficiency in the landcover classification was identified across the southern region where low dense vegetation (e.g. low shrubs and/or tall grasses, rushes and reeds) could not reliably be differentiated from open pasture. This vegetation is highly variable, often associated with a range of other taller vegetation or is distributed in very small patches. While modified, it is important habitat for small faunal species such as the southern brown bandicoot and therefore the remote sensing was refined further based on ground surveys undertaken by Council and manual interpretation of aerial imagery. As a result, an additional 'modified scrub' landcover classification was added and the connectivity modelling updated accordingly.

7.4 Species connectivity

Modelling was completed for three dispersal guilds, using eastern yellow robin, greater glider and southern brown bandicoot as the focal species (refer to Table 11). All exhibited significant differences in their responses to the shire's landscape. See Figure 5, Figure 6 and Figure 7 for detailed mapping of each focal species dispersal network.

Table 11. Dispersal guilds modelled for the Cardinia Shire biolink connectivity study

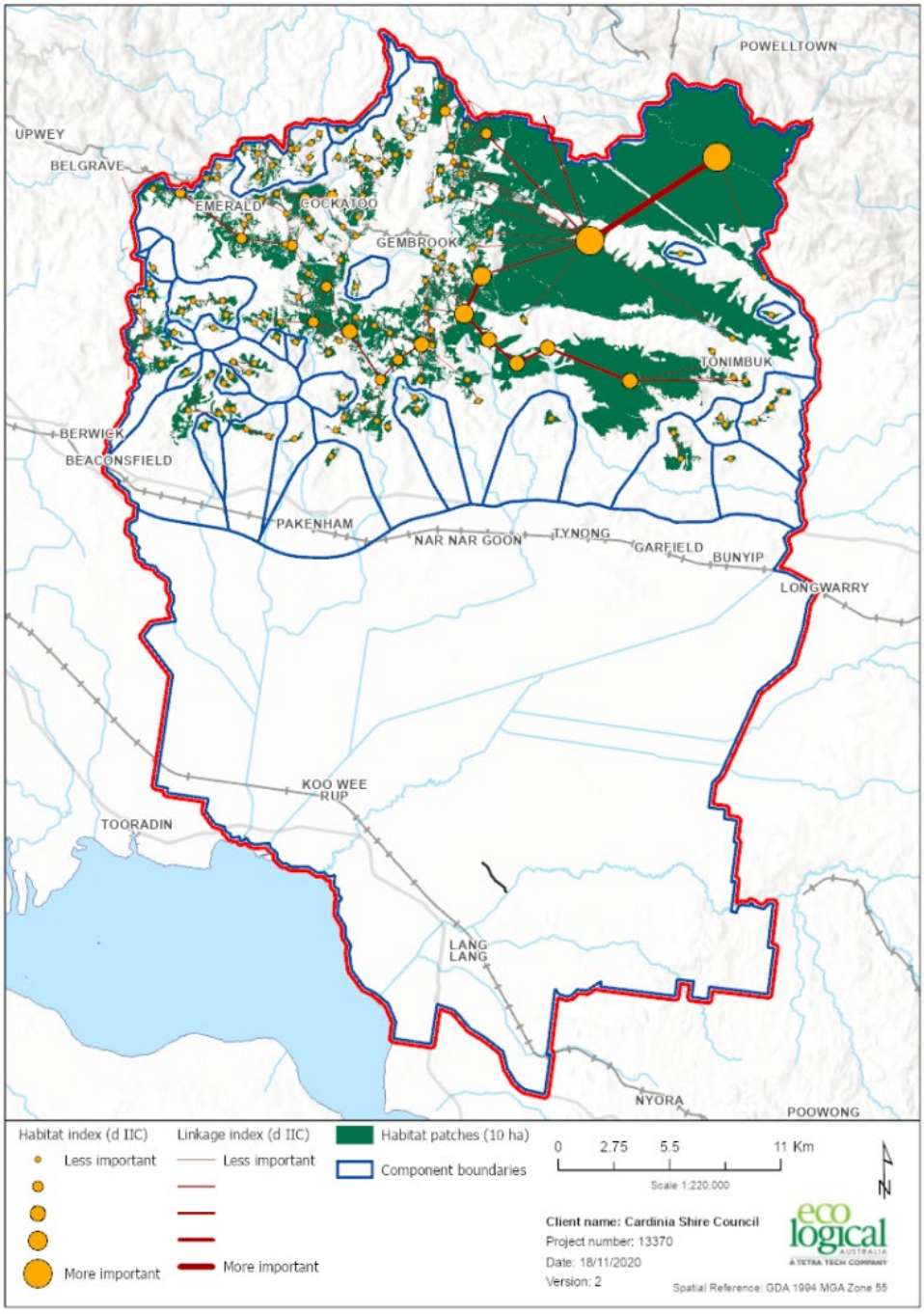
Focal species	Mobility	Patch size	Habitat	Connectivity elements	Urban tolerance
Greater glider	Lower	High	Forest	Forest and woodland	Lower
Eastern yellow robin	Moderate	Moderate	Forest and woodland	Forest, woodland, scrub, heathland	Lower
Southern brown bandicoot	Higher	Moderate	Woodlands, scrubs and modified scrubs	Forest, woodland, scrub, heathlands and modified scrubs	Higher

7.4.1 Greater glider

The greater glider represents those species with low dispersal abilities that are restricted to large, forest habitat patches of at least ten hectares in size. It was assumed to be able to utilise connectivity elements with trees as stepping-stones for dispersal (i.e., forest or woodland connectivity elements).

The larger habitat patch requirements and reduced mobility can be seen in the greater number of connectivity components in the north of the shire, when compared to the modelling outputs for eastern yellow robin. Habitat for this species is predominantly associated with Bunyip State Park in the north-east and Cardinia Reservoir and RJ Chambers Flora and Fauna reserve in the north-west, with a single link connecting these areas through Pakenham Upper as shown in Figure 5.

Figure 5. Connectivity network indices for greater glider



Numerous small components, comprised of few habitat patches, were identified on the lower slopes of the hills to the immediate north of the Princes Freeway. This can partly be explained by an increase in land clearing and fragmentation in these locations, but also due to a reduced cover of 'forest' habitat types as vegetation grades into lower, more open woodland in these areas.

While habitat appears to be extensive, the modelling indicates connectivity for this species is poor around the southern edge of Cardinia Reservoir and to the south through Guys Hill and Beaconsfield Upper. This may be due to the increased urbanisation throughout the area, resulting in the introduction of movement barriers (e.g. major roads) and the removal of stepping-stones (e.g. scattered trees).

7.4.2 Eastern yellow robin

In the context of this study, the eastern yellow robin is a woodland bird species with moderate dispersal ability that requires forest or woodland habitat patches of at least five hectares in size. It was assumed to be able to utilise connectivity elements classified as forest, woodland, scrub and heathland as stepping-stones for dispersal.

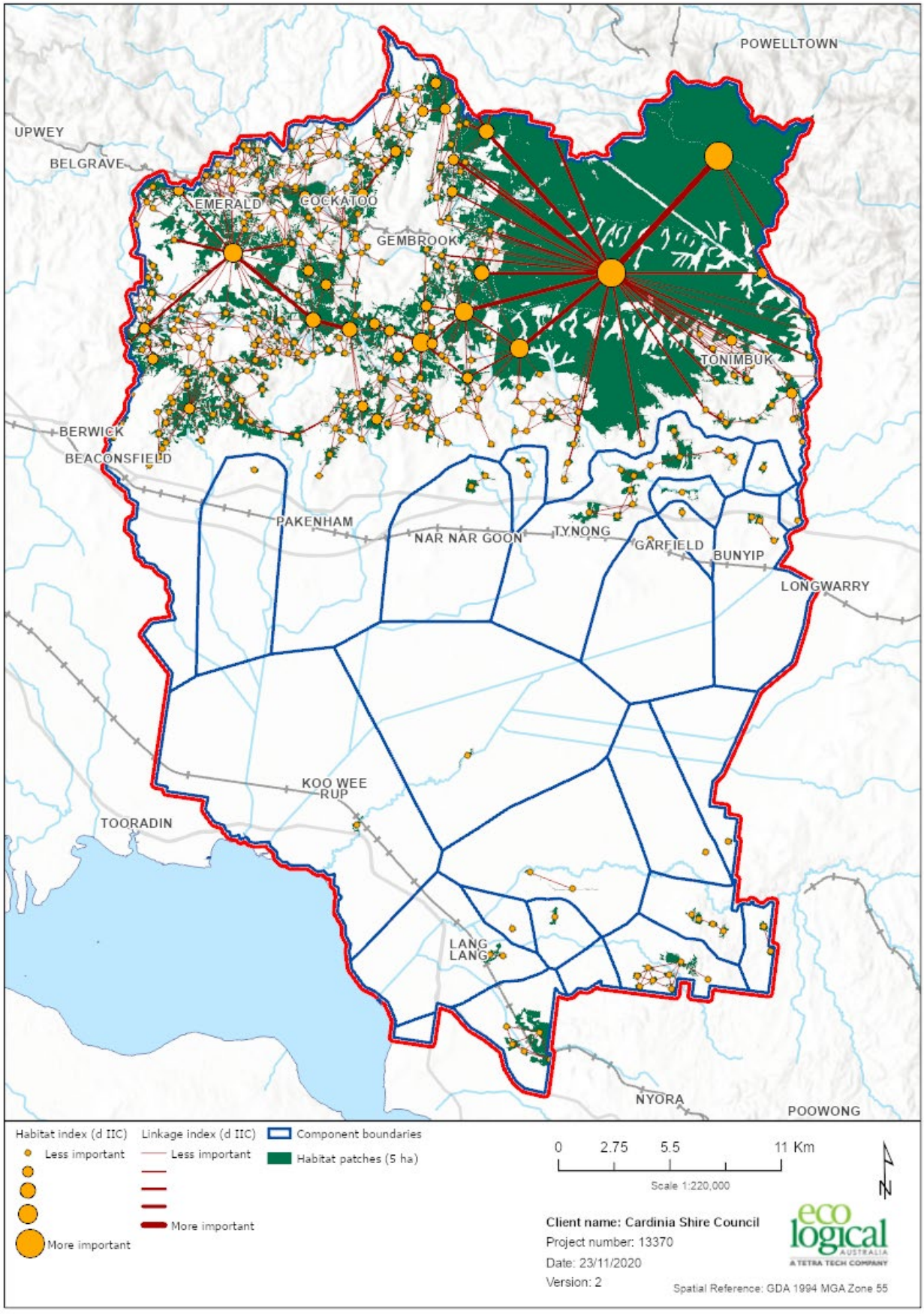
For this species, the shire's landscape is well connected in the north, with two distinct habitat clusters associated with Cardinia Reservoir in the west and Bunyip State Park to the east as show in Figure 6.

The primary corridor connecting these two areas consists of a series of large habitat patches to the north of Pakenham Upper, centred on RJ Chambers Flora and Fauna Reserve and Gembrook bushland reserve. Two smaller corridors were identified to the north, around Pancake Creek, and the south through private land above Pakenham. However, the strength of these smaller corridors is relatively low with few viable alternative pathways.

As the hills fall away to the plains in the south and vegetation becomes scarce, fragmentation increases with several isolated habitat clusters identified north of Tynong, Garfield and Bunyip. This includes one larger cluster of patches with relatively good connectivity centred on Mount Cannibal and woodlands along Cannibal Creek to the south.

Moving south onto the plains, habitat of a suitable size and nature to maintain a population disappears almost entirely, with notable habitat limited to woodlands to the south of Lang Lang and Heath Hill. Based on the modelling, these woodlands are poorly connected for this species.

Figure 6. Connectivity network indices for eastern yellow robin



7.4.3 Southern brown bandicoot

The southern brown bandicoot represents a ground-dwelling mammal with a moderate to high dispersal ability, that is restricted to scrub and woodland habitat patches of at least three hectares in size in the south of the shire. It was assumed to be able to utilise all connectivity elements as stepping-stones for dispersal (i.e. forest, woodland, heathland, scrub and modified vegetation).

Despite complimenting the woody vegetation with 'modified scrub' identified through field assessments and manual interpretation of aerial imagery, and aggregating habitat within 20 metres of each, the modelling identified very few areas of core habitat for this species as displayed in Figure 7. Areas of relatively high habitat density were limited to vegetation around the Cardinia Creek drain and Koo Wee Rup, Bunyip River Drain, Garfield, Tynong, Bunyip, Lang Lang and Heath Hill. Given the high level of fragmentation, many of the smaller, isolated patches not identified above are unlikely to currently support viable populations.

The landscape did not appear to support sufficient connectivity elements to facilitate dispersal between areas of core habitat, resulting in numerous small components being identified. The largest component covered the area surrounding Koo Wee Rup and Adams Creek national conservation reserve (NCR) in the south of the shire. While this species is known to occur in Adams Creek NCR to the south-east of Koo Wee Rup, this represents the edge of the species' range in the region and habitat to the east around Heath Hill may be considered marginal. The other important area of core habitat was centred around Koo Wee Rup and the Cardinia Creek drain to the north. Connectivity was primarily associated with the drain network and roadside vegetation, providing access to multiple large patches.

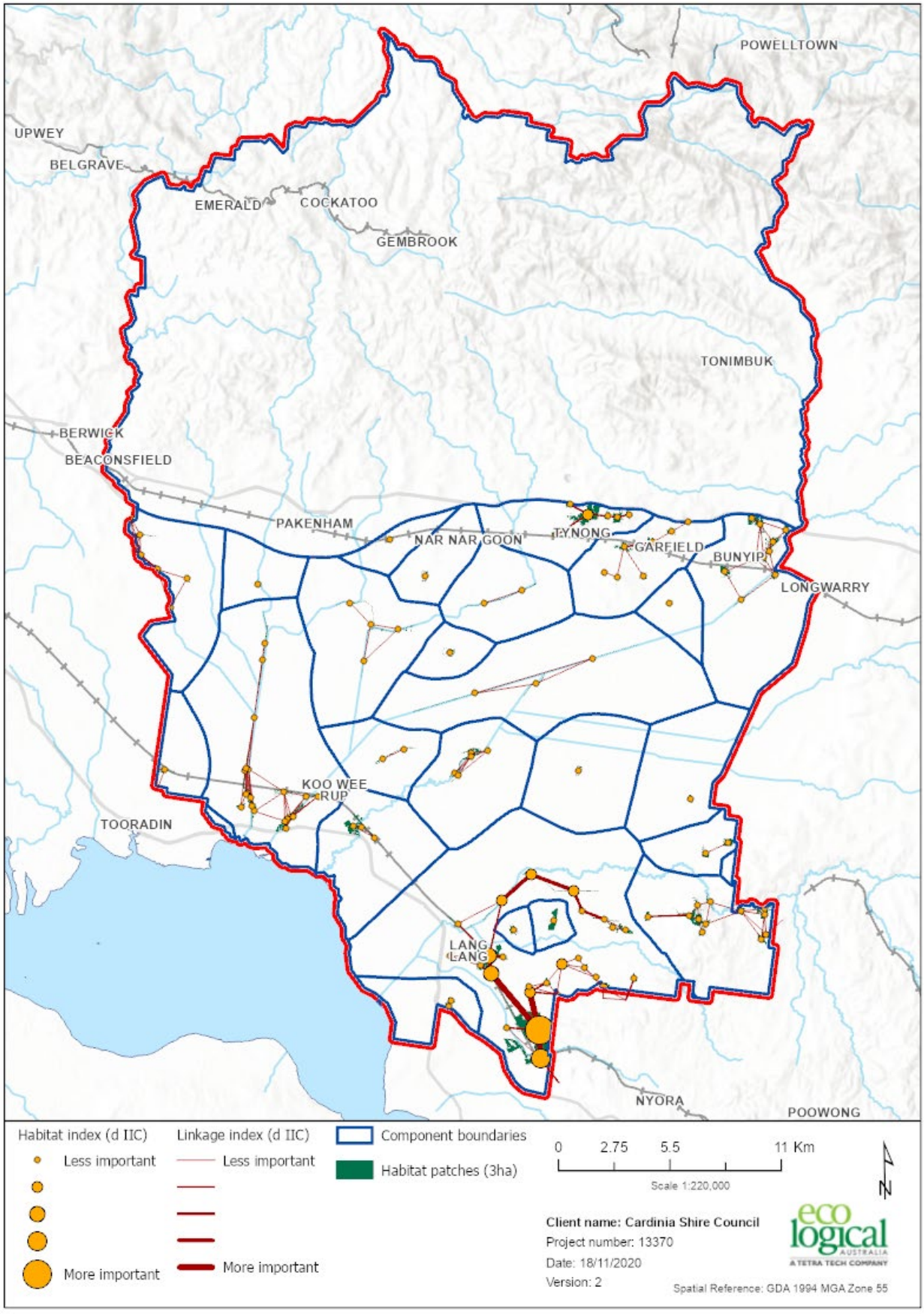
Connectivity in Bayles, Garfield and Tynong were centred around several relatively large habitat patches, with linkages relying on movement through or around residential areas. To the south, the Bunyip River Drain was identified as three continuous, narrow patches reliant on modified and recolonising scrubs along the levy banks and roadside drains.

While the number of habitat patches were limited, the modelling has captured many of the known populations of southern brown bandicoot throughout the shire and is therefore considered representative of the viability of populations across the broader landscape, at least in the short to medium term.

Given the heavy reliance on major drains and road reserves for core habitat or connectivity, the permanency and quality of habitat is likely influenced by land management actions, including slashing. The potentially short life of this vegetation, particularly with regard to the persistence of connectivity elements such as long grass, blackberries and immature scrub, is of particular concern to the long-term provision of connectivity within this landscape

Optimal habitat structure and composition for Southern brown bandicoots is detailed in the *Southern Brown Bandicoot Habitat Protection Strategy and Environmental Significance Overlay.* (Bernadette, 2016)

Figure 7. Connectivity network indices for southern brown bandicoot



7.5 Landscape connectivity

To provide an overview of connectivity across the landscape for all land-based (terrestrial) species, data from the various connectivity scenarios has been compiled into a single, weighted map. Figure 8 describes the existing and future biolink nodes and corridors. 'Priority' and 'future' biolink corridor types have been established to delineate biolinks in order of importance for conservation works. A third specific corridor type was also established in developed areas. The three corridors types are summarised on Table 12.

Table 13 lists the 46 priority nodes which represent areas of core habitat crucial to supporting biodiversity and which require connectivity within the landscape. Table 16 summarises the 48 priority corridors that can connect the biolink nodes.

Table 12. Biolink Plan corridor types

Corridor name	Goal	Details
Priority corridor	Protect and enhance structural and functional habitat as a priority	Implement all defined seven conservation management activities as the highest priority
Future corridor	Protect and enhance structural and functional habitat as a second priority	Implement all defined seven conservation management opportunities after priority corridor activities have been actioned.
Conservation corridor	Retain and enhance the functionality of habitat. No increase in the extent of the corridor.	Enhance corridors through a limited range of conservation activities such as pest plant and animal management to complement priority corridors. Large scale revegetation is excluded from conservation corridors.

Figure 8. Existing and potential biolink nodes and corridors

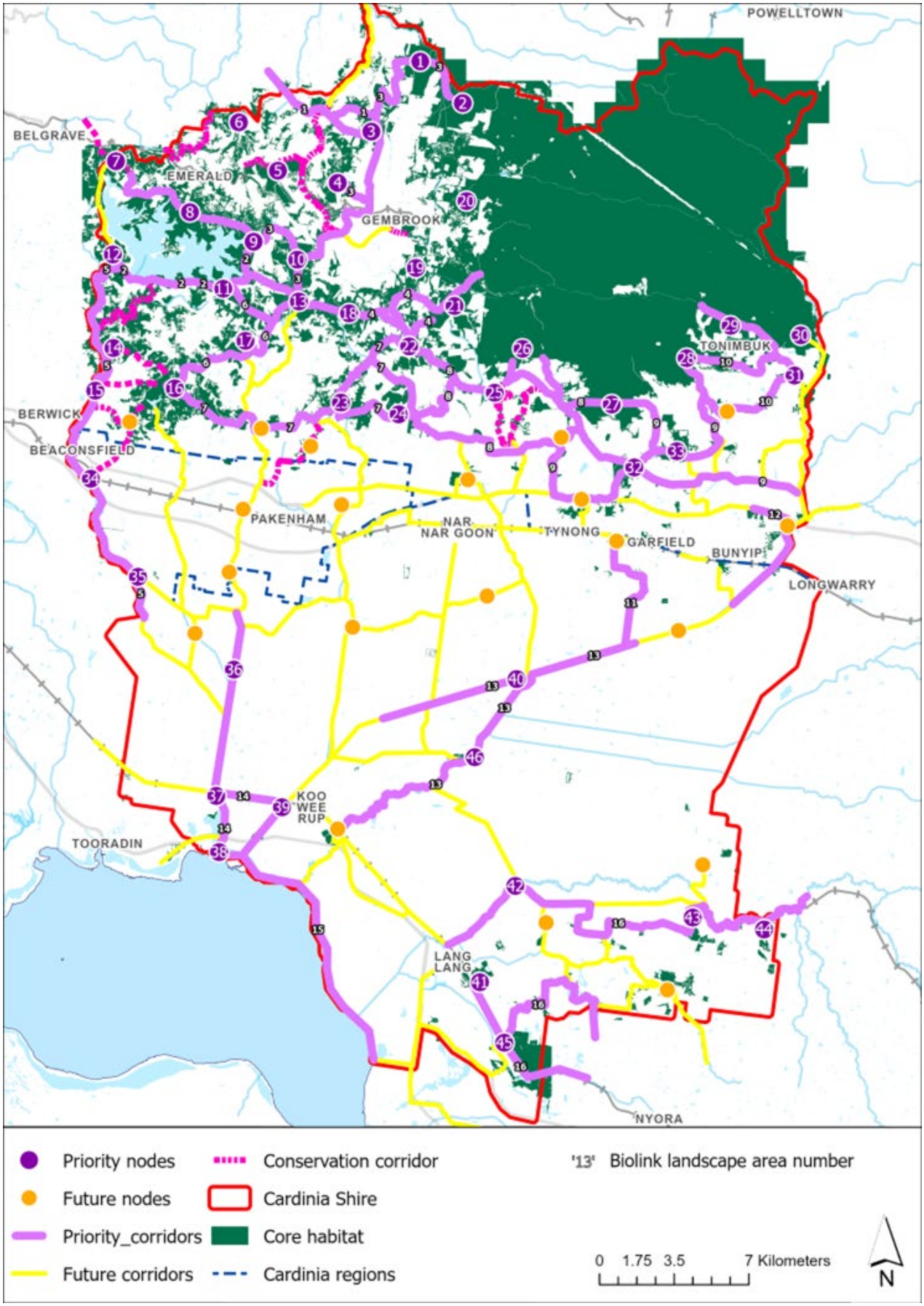


*Table 13. Biolink nodes in Cardinia Shire**

No	Biolink node (BN)	Region
1	Kurth Kiln regional park (N)	Northern
2	Kurth Kiln regional park (E)	Northern
3	Helios Camp bushlands	Northern
4	Cockatoo East bushlands	Northern
5	Wright Forest	Northern
6	Stewart Road bushlands	Northern
7	Cardinia Reservoir (N)	Northern
8	Cardinia Reservoir (NE)	Northern
9	Cardinia Reservoir (E)	Northern
10	Bourkes Creek bushlands	Northern
11	Cardinia Reservoir (S)	Northern
12	Cardinia Reservoir (W)	Northern
13	RJ Chambers Flora and Fauna Reserve	Northern
14	Upper Beaconsfield nature conservation reserve / Stony Ck bushlands	Northern
15	Upper Cardinia Creek parklands	Northern
16	Beaconsfield nature conservation reserve	Northern
17	Kitchen Creek bushlands	Northern
18	Gembrook bushland reserve (W)	Northern
19	Upper Diamond Creek bushlands	Northern
20	Bunyip state park (NW)	Northern
21	Backhouse Road bushlands	Northern
22	Upper Bessie Creek bushlands	Northern
23	Upper Deep Creek bushlands	Northern
24	Nar Nar Goon bushland reserve	Northern
25	Back Creek / Maryknoll bushlands	Northern
26	Bunyip state park (SW)	Northern
27	Bunyip state park (S)	Northern
28	Bunyip state park (SE)	Northern

No	Biolink node (BN)	Region
29	Tonimbuk bushlands	Northern
30	Bunyip state park (E)	Northern
31	Upper Bunyip River bushlands	Northern
32	Brew Road bushlands	Northern
33	Mt Cannibal	Northern
34	Cardinia Creek parklands	Urban growth
35	Lower Cardinia Creek	Urban growth
36	Cardinia drain	Southern
37	Cardinia Ck outlet bushlands	Southern
38	Western Port Coastline	Southern
39	Bunyip River outlet bushlands	Southern
40	Main Drain scrublands	Southern
41	Lang Lang bushlands	Southern
42	Lang Lang River bushlands	Southern
43	Lyons Road bushlands	Southern
44	Hook Road bushlands	Southern
45	Adams Ck nature conservation reserve	Southern
46	Bayles bushlands	Southern

*Figure 8 shows the biolink nodes as purple dots with the corresponding number listed in this table

Given the differences in landcover, habitat types and connectivity priorities, this mapping utilises the model scenarios, as outlined in Table 14 to present connectivity across the different landscape regions

Table 14. Modelling scenarios compiled to represent overall landscape connectivity in Cardinia Shire

Region	Scenarios used
North	• low mobility (arboreal mammal): 150 m inter-patch distance and 10ha minimum patch size (greater glider) • moderate mobility (bird): 900m inter-patch distances and 5ha minimum patch size (eastern yellow robin) • moderate mobility (ground-dwelling): 1500m inter-patch distances and 5ha minimum un-aggregated patch size (southern brown bandicoot).
Urban growth zone	• moderate mobility (bird): 900m inter-patch distances and 5ha minimum patch size (eastern yellow robin) • moderate mobility (ground-dwelling): 1500m inter-patch distances and 1ha minimum aggregated patch size (southern brown bandicoot).
South	• moderate mobility (bird): 900m inter-patch distances and 5ha minimum patch size (eastern yellow robin) • moderate mobility (ground-dwelling): 1500m inter-patch distances and 3ha minimum aggregated patch size (southern brown bandicoot).

Given the combination of different models, the map in Figure 8 is considered valuable for consideration of landscape scale priorities only. The biolink interactive map shows more detailed landscape connectivity for high, moderate and low mobility fauna. Demonstration maps of biolink corridor modelling can be found in Appendix H.

7.5.1 Northern region

For all species the landscape was relatively well connected in the north, with habitat centred on Bunyip State Park (166 km^2) in the east and Cardinia Reservoir (12.9 km^2) in the west. These reserves comprise of a wide range of intact core habitats for species and effectively represent extensive nodes in the landscape supporting biodiversity to the broader region. Notwithstanding the security fence around the perimeter of Cardinia Reservoir which acts as a barrier to specific suites of species. Connectivity between these areas were limited to several narrow corridors around Pancake Creek in the north (BC3), Pakenham Upper and RJ Chambers Flora and Fauna Reserve in the centre (BC4) and above Pakenham through private land in the south (BC7). For less mobile species these corridors were restricted to a single, central link through Pakenham Upper and RJ Chambers Flora and Fauna Reserve (BC4).

Moving away from Bunyip State Park and Cardinia Reservoir, fragmentation increased, and connectivity reduced. This resulted in numerous small components appearing along the foothills immediately north of the Princes Freeway where habitat persisted yet did not have sufficient connectivity elements in the landscape to provide linkages to Bunyip State Park and Cardinia Reservoir. The influence of urban development and more intensive peri-urban activity (i.e. higher resistance) was evident in and around Beaconsfield Upper and Guys Hill in the west. Despite numerous habitat nodes throughout this area, connectivity was poor for low mobility species with multiple small components modelled.

Connectivity was poor for low mobility species north of Emerald with nodes around Macclesfield and through to Yellingbo Nature Conservation Reserve (661 hectares) including the Sedge-rich Eucalyptus camphora Swamp vegetation community. These nodes are generally isolated from Bunyip State Park.

A total of 33 biolink nodes were identified throughout the north region in locations where multiple patches of core habitat were present within high levels of connectivity between them. These nodes are spread evenly across much of the region and are indicative of the extensive habitat and biodiversity values present in Cardinia Reservoir, Bunyip State Park and the many large reserves nearby.

7.5.2 Urban growth area

Due to the fragmented and heavily urbanised nature of the landscape within the urban growth boundary from Beaconsfield to Pakenham East, the species parameters for southern brown bandicoot (i.e. a more mobile species) were modified to reduce the minimum habitat patch size and allow smaller areas of vegetation to be captured in the modelling. This has resulted in connectivity outputs which better represent the extent of habitat and connectivity for a range of common, urban-tolerant species such as white-plumed honeyeater (*Lichenostomus penicillatus*), pied butcher bird (*Cracticus nigrogularis*), garden skink (*Lampropholis guichenoti*), common ring tail possum (*pseudocheirus peregrinus*) and growling grass frog (*litoria raniformis*). These outputs provide an indication of the current, limited linkages along with potential opportunities to improve connectivity in this region.

As expected, patches and linkages were largely restricted to waterways, and in particular Cardinia Creek and Gum Scrub Creek in the west of the growth area (BC5). These corridors retained sufficient vegetation along the creek line and, importantly, adjoining land to ensure core habitat and connectivity elements were present.

At the western end of the growth area the narrow, vegetated corridors associated with Toomuc Creek and Deep Creek provided limited connectivity due to the heavily urbanised nature of Pakenham. Vegetation within the rail reserve and along the Princes Freeway and Princes Highway provide limited east-west linkages for species such as the southern brown bandicoot, overall these corridors are of lower value when compared to the rest of the landscape. While these corridors play a role in connectivity along the north and south of the shire, the low connectivity index scores can be attributed to a scarcity of larger habitat patches to the south and therefore lesser connectivity value (i.e. there are limited locations for the species to go). As a result, connectivity within the west of the urban growth area is considered limited to only species considered tolerant of heavily modified, urban landscapes.

These corridors above have been identified in the growth corridor precinct structure plans and are a focus for ‘future potential corridors’ that link up with the creek lines and other assets and are discussed in Section 8.2.

7.5.3 Rural townships

Rural townships within the shire similarly to the urban growth corridor also contain fragmented vegetation within an urbanised environment. The protection of people and property through risk-based planning is the priority land management outcome in these locations some of which are located within a bushfire management overlay. Conservation corridors (refer Section 8.3) have been located along waterways including Emerald (CC11), (CC12), Cockatoo (CC9, CC10) and Maryknoll (CC13, CC14, CC15). No terrestrial corridors are located within townships.

Vegetation connectivity within townships is generally clumped and spatially separate and is considered limited to provide habitat for species such as the White-plumed honeyeater (*Lichenostomus penicillatus*), Pied butcher bird (*Cracticus nigrogularis*), Garden skink (*Lampropholis guichenoti*) and Common ring tail possum (*pseudocheirus peregrinus*). Notwithstanding this, significant species such as Lyrebirds, Greater gliders, Yellow bellied gliders and the Powerful owl, which preys on ringtails possums still persist within a range of the hills townships. The population of the endangered Emerald Star Bush is also endemic to the Emerald township area. In central and southern townships specific habitat opportunities exist for the endangered southern brown

bandicoot (*Isoodon obesulus*). These township biolink opportunities have been referred to as ‘conservation corridors within the township.

The State Emblems Conservation Area seeks to link threatened species such as the Helmeted Honeyeater and Leadbeaters Possum with habitat in Cockatoo and Emerald.

7.5.4 Southern region

In contrast to the north, core habitat and connectivity elements in the south were sparse, being associated primarily with scrub along drainage lines and roadsides, property boundaries and small woodland plantations or reserves on the outskirts of settlements. As a result, connectivity was poor and limited to discrete clusters of habitat patches with sufficient connectivity elements to allow for dispersal along the associated corridors. This can be seen in the numerous small components that were modelled across the southern region for the more mobile southern brown bandicoot. Important habitat nodes were identified around the Cardinia Creek drain and Koo Wee Rup, Bunyip River Drain, Garfield, Tynong, Bunyip, Lang Lang and Heath Hill.

The modelling showed a heavy reliance on narrow, vegetated drains, roadsides or farm plantings (e.g. shelter belts) to provide connectivity. This can be attributed to the lack of woody vegetation (e.g. scattered trees or small patches) remaining within private property, when compared to the north, and a prevalence of swamp scrub which readily re-colonises wet sites on the plains. The resulting scrub-dominated vegetation tends to be homogenous with limited structural complexity and is therefore only suited to smaller species able to utilise such environments (e.g. southern brown bandicoot or swamp skink).

In the southernmost extent of the shire around Lang Lang and Heath Hill, numerous small bushland reserves and woodland remnants (both patches and scattered trees) contributed to higher levels of connectivity for more mobile species. This connectivity however did not carry through to species considered to be less mobile (e.g. woodland birds), for which the landscape is still considered to be fragmented in the south.

Further, vegetation in this southern-most area tended to be dominated by heathy and grassy woodland remnants, rather than recolonising swamp scrub. These remnant woodlands are therefore likely to have greater functional and structural complexity and provide habitat for a broader range of species despite limitations with connectivity.

8 Strategic connectivity priorities

A landscape with high ecological connectivity is one which provides sufficient structure to allow free movement of individuals and genes, supporting critical life cycle events, ecosystem functions (e.g. pollination) and viable populations (e.g. recruitment). Management priorities therefore need to consider the physical location and nature of habitat and connectivity elements (often referred to as 'structural connectivity') in addition to the ecological needs and behaviour of the species that are the target of conservation efforts. The combination of these factors (often referred to as 'functional connectivity') underpins a species ability to persist and thrive within a landscape and is vital to the development of successful connectivity priorities for the conservation of biodiversity across Cardinia Shire.

This section provides the guiding principles for biolink connectivity within Cardinia Shire at both a regional and local level and incorporates state strategic bushfire planning into the setting of corridors. The plan is consistent with Council's *Biodiversity Conservation Strategy* and *Weed Management Strategy* framing priorities under the themes of 'protect, enhance and engage.'

To realise the multiple goals of this plan for safe communities and a sustainable natural environment the plan is considerate of the strategic direction set out in the Metropolitan Bushfire Management Strategy (2020) (MBMS) and utilises local expertise from the Municipal Fire Management Planning Committee (MFMPC) to guide the implementation of biolink corridors. In line with the MBMS defined 'high risk' areas, no terrestrial biolink corridors are located within townships. Where significant waterways are located through townships the Biolink Plan has identified 'conservation corridors' to be enhanced to protect the waterway, while the extent of the waterway riparian vegetation will not be increased.

Collaboration with the MFMPC will involve the committee providing expertise on the mitigation actions for conservation works that could present a bushfire risk to people or property. Section 9.1 identifies the management principles that provide direction where there are conflicts with conservation management proposals and maintenance of landscapes that are safe to people and property. Section 10.4 identifies the decision support matrix for projects to respond to the different MBMS landscape risk areas. Collaboration with the MFMPC is identified as ongoing throughout the life of the biolink action plan.

Utilising the computer corridor modelling, each individual biolink corridor was post-processed and reviewed from a desktop assessment at 1:6,000 scale to test the location of the corridor to be considerate of achieving the project goals of sustainable connected corridors for species which are also safe to people and property. This included assessment and where required realignment of corridors to consider the following.

- Identifying the most sustainable corridor alignment that does not conflict with the '150m bushfire site assessment area' from buildings and dwellings (defined within clause 44.06 of the Bushfire management overlay). The 150m distance is effectively treated as a minimum setback distance where functional biolink corridors are excluded. Where biolink corridor realignments could not avoid an intersection with the 150m setback zone, these intersections were minimised. Refer section 9.3.2 property scale biolink planning and Appendix F for more detail.
- Where possible corridors were moved and aligned to low lying creek gullies and waterways which represent a comparatively lower fire risk to dryer terrestrial areas. Gullies and waterways were typically located a greater distance from developed and agricultural areas.
- In order to minimise the bushfire risk from prevailing north westerly dominated weather patterns, where possible corridors were aligned to the south eastern aspect of properties to reduce potential vegetation bushfire risk. Where corridors were located along the north western aspect, as a preference these are located within low lying creek gullies and waterways.
- Points of escape from a property during a fire event.
- Prioritising alignment within public reserves managed for conservation.

- Prioritising rural properties with intact vegetation located away from dwellings and agricultural zones.

A list of the fire management considerations that have informed biolink corridor alignment to manage bushfire risk have been summarised in Appendix J.

8.1 Regional priorities

Regional priorities are focused on protecting and enhancing critical elements within the existing connectivity network while identifying opportunities for significant, landscape-scale improvements. The priorities for the north, south and urban growth area regions are outlined on Table 15.

Table 15. Regional connectivity priorities

Region	Description
Northern	Within the highlands southern fall bioregion there is an emphasis on the protection and enhancement of existing high-quality habitat and the features which connect them. In particular, the protection of the most significant regional corridor between Bunyip State Park and Cardinia Reservoir to the north of Pakenham Upper (biolink corridor number 4 (BC4)) is of the greatest priority. Improvement of corridors to the north around Pancake Rock (BC3) and south of Pakenham Upper (BC7) will further strengthen the network. The enhancement of connectivity around Beaconsfield Upper in the east (BC5) and along Cannibal Creek and Mount Cannibal in the west (BC9 and BC10) are also considered to be of a high priority. Menzies Creek, Macclesfield Creek and Cockatoo Creek are identified by the Victorian Environmental Assessment Council as a 'State Emblems Conservation Area' (Victorian Environmental Assessment Council, 2013). Priorities to enhance the habitat of these waterways are defined as 'future biolinks' and within townships as 'conservation corridors.' All landscape scale connectivity initiatives within the vicinity of the township areas identified in the plan will be considerate of the need to manage fuel loads and designed in collaboration with the Municipal Fire Management Planning Committee.
Urban Growth Area	The primary purpose of the central, densely populated urban growth area is for residential and commercial outcomes. Functional corridors are typically restricted to creek lines and smaller patches of native vegetation which provides habitat for mobile species tolerant to disturbance. The key focus for this region is the protection and enhancement of existing corridors in the west around Cardinia Creek and Gum Scrub Creek (BC5) to limit further impacts associated with urban infill. In the west, the creation of corridors capable of supporting the movement of a diversity of species along Deep Creek and Toomuc Creek as well as the reserves associated with the Prince's Highway, Prince's Freeway and rail line, should be considered as future potential biolink corridors. Utility easements such as transmission power lines, gas easements should also be considered for the potential to support connectivity elements where this does not conflict with the primary purpose of the utility. These easements naturally extend across a wide area of the growth corridor and offer significant opportunities to connect creek corridors. DELWP's *Growling Grass Frog Masterplan* supports the creation of new habitat and protection of existing habitat along the above creek corridors identified. The masterplan identifies areas of strategic importance for investment and protection along: • Cardinia Creek, • Gum Scrub Creek • Toomuc Creek and the creek waterway east of Toomuc Creek. This is elaborated on in Section 10.1.4

Region	Description
	Within the growth corridor the community value smaller parcels of native vegetation that act as habitat for moderate to highly mobile species. In public spaces this includes smaller green spaces such as 'pocket parks', drainage lines, recreation reserves, retarding basins and utility easements. On private property this can include patches of scattered trees. Council's gardens for wildlife program can foster support to create habitat for native species within urban properties. Given space required to create new habitat in heavily urbanised areas within the growth corridor is limited, enhancement of these corridors will need to have a strong focus on improving the function of existing habitats.
Southern	The Gippsland plain bioregion is characterised by large, rural properties of predominately cleared land that is subject to flooding. Much of the remaining habitat is limited to the constructed drains which intersect the region, with complementary habitat persisting in road reserves and shelterbelts. Review of the extent of threatened species records in the shire reveals that the highest concentration of threatened species within the shire is located along the interface of the Highlands Southern Fall and the Gippsland Plain Bioregions. This could be due to the interface comprising of a combination of plant communities from both bioregions. Enhancement of indigenous vegetation along this interface could yield the greatest benefits for the largest suite of threatened species. The effective, long-term management of habitat associated with the drains and adjoining road reserves and private land is considered critical to protecting and improving of connectivity within and between the few fragmented patches of core habitat remaining in the region. In particular, the slashing and removal of vegetation has the potential to continuously fragment linkages and core habitat, further reducing the viability of existing populations and preventing colonisation of isolated habitats. Ensuring sufficient vegetation persists in these environments to maintain the permanency of core habitat and the associated stepping-stones connecting them is a key focus for the creation and improvement of corridors in the region. In the south, the creation of corridors linking Adams Creek NCR and Koo Wee Rup along the unused South Gippsland rail reserve and South Gippsland Freeway are future priorities for improving connectivity at a landscape scale. A potential third corridor to the north connecting core habitat around Bayles is proposed to further improve landscape-scale connectivity. These corridors will require investment in habitat creation on private land adjoining the narrow road reserves, freeway and rail corridors to fully realise the connective potential of the biolink. Around Lang Lang, the focus is primarily on protecting and improving corridors between Adams Creek NCR and core habitat to the north and east. Protecting and enhancing the cover of vegetation along Lang Lang River while developing of new corridors between existing patches along the southern boundary of the shire is considered to be of a high priority. The Western Port coastal biolink corridor is a notably challenging area (BC-15). Council is not delegated Committee of Management for this Ramsar listed area which is habitat to threatened species and threatened vegetation communities. This area is currently experiencing coastal erosion, storm surges, pressures from agriculture and challenges to water quality and drainage which impact the coastal vegetation communities and mudflats. Many of these pressures are interrelated and compounding each other. The area is managed by multiple government and private landholders, has poor statutory planning protection and is poorly funded. Most of the coastline is managed by the Department of Environment, Land, Water and Planning. A detailed study is required focusing on sustainable land management outcomes on private land where coastal storm surges, drainage needs, and agricultural values can be balanced with the establishment of a coastal buffer for coastal vegetation communities. An opportunity exists utilising Victoria's

Region	Description
	proposed ‘Resilient Coast Guidelines’ document and projects such as the Victorian Coastal Adaptation Pathways Project to address this issue.

8.2 Local priorities

A set of local connectivity priorities have been developed to ‘protect and enhance’ existing biolink corridors, and ‘connect’ currently isolated habitats through the creation of new biolink corridors where they are safe to people and property. Potential measures to further ‘engage and educate’ stakeholders on connecting landscapes are also outlined in Section 8.3.3. These priorities enhance the actions identified in the Council’s *Biodiversity Conservation Strategy* and the *Weed Management Strategy*.

These priorities are considerate of bushfire management planning and recognise that improvements can be achieved through a diversity of on-ground actions specific to each individual location. The aim of which will be to improve the overall extent of habitat and/or increase the strength and number of linkages to create resilience across the landscape that are also safe to people and property. Given the most suitable location for investment will depend on a range of factors beyond the scope of the connectivity analysis, such as land use and tenure, planning objectives, location of threatened species and habitats, existing conservation initiatives and community support, a prioritisation analysis has been prepared to inform investment priorities at a landscape scale (refer to Section 10.5 prioritisation analysis). This analysis draws on the local and regional connectivity modelling outputs and existing biodiversity data to categorise the study area into 10-metre square grids to provide relative conservation value.

8.3 Conservation corridors

Priority and future biolink corridors aim to increase functional and structural connectivity for species. The bushfire risk in densely populated areas and townships limits the ability to create and extend fully functional biolink corridors for a diverse range of species. For this reason, a third biolink corridor which is defined as a biolink 'conservation corridor' has been established to achieve limited connectivity for species within densely populated areas while also managing bushfire risk to an acceptable level. The goals within all conservation corridors are to enhance the quality of habitat through a set of limited conservation activities. There is no direction to increase the extent of any conservation corridor and as a consequence no large-scale revegetation works are proposed in these locations.

Conservation corridors have been identified within two landscape types which include:

- waterways within townships
- areas where a priority or future biolink connection is unrealistic as the corridor is primarily located within the 150m bushfire site assessment area from dwellings.

Activities proposed in conservation corridors are limited to:

- pest plant and animal control
- artificial habitat construction
- ecological burning and construction of water body habitat
- stimulating natural ecological processes
- community awareness programs.

Existing native vegetation within terrestrial conservation corridors can provide refuge for highly mobile species and act as stepping-stones between core habitat areas. Low and moderate mobility species are less likely to use these terrestrial corridors due to bushfire risk which directs that vegetation should be isolated and spatially separate.

The protection of riparian areas presents as one of the most significant opportunities to improve landscape condition across a range of biodiversity, water and carbon objectives (Campbell, 2008). The conservation benefits to protect these waterways is elaborated in section 9.3.6 and is supported by Melbourne Water's ongoing Stream Frontage Management Program.

Biolink conservation corridors have been identified along waterways within townships, including Menzies Creek, Woori Yallock Creek and Cockatoo Creek waterways in the north, Stoney Creek in Upper Beaconsfield and Back Creek in Maryknoll. These conservation corridors provide important connectivity for species throughout the broader region. The Victorian Environmental Assessment Council has nominated Menzies Creek, Woori Yallock Creek and Cockatoo Creek as part of the 'State Emblems Conservation Area' (Victorian Environmental Assessment Council, 2013).

The retention of riparian creek line vegetation within conservation corridors compliments DELWP's fire management zone planning for defined 'Landscape management zones' which aims to reduce overall bushfire hazard at a landscape scale, while supporting ecological resilience. This is demonstrated by the management of Cockatoo Creek adjacent to Wrights Forest in Cockatoo. Notwithstanding this, fuel management (including planned burning) in the Landscape management zone away from the riparian corridor may be required at times to support broader landscape risk reduction by reducing the overall fuel hazard.

The identification of conservation corridors as an environmental priority in the landscape enables Council, stakeholders and the community to allocate and apply for resources that can have multiple land management benefits. This could include enabling increased weed control actions which can reduce biomass and bushfire threat along creek lines (DELWP, 2017) while also improving habitat.

Opportunities may exist on a site-by-site basis to undertake spatially distant and isolated revegetation within terrestrial areas of conservation corridors including within the 150m bushfire site assessment area of a dwelling. Spatially distant and isolated planting can contribute to stepping-stone habitat for species. This type of planting must be designed not to increase the bushfire threat to people or property which is elaborated on in section 9.3.2. and Figure 10.

8.3.1 Protect and enhance

Management priorities to 'protect and enhance' local connectivity will primarily be focused on the northern region of the shire, with an emphasis on the biolink corridors linking Bunyip State Park and the Cardinia Reservoir with smaller core habitat nodes in the local vicinity.

The management priorities to protect and enhance the shire's current connectivity network include:

- prevent the loss of habitat and connectivity elements, both in terms of quality and extent, within core habitat nodes and along biolink corridors
- consolidate and expand areas of core habitat and associated local linkages through protection of existing habitat and creation of new core habitat using existing assets (e.g. areas of potential habitat and/or connectivity elements)
- consolidate and expand priority habitat patches and connectivity elements along priority corridors to improve resilience within the landscape. This will include reducing the distances between habitat patches to cater for a range of dispersal guilds
- improve structural connectivity within existing priority corridors and core habitat nodes through the addition or enhancement of a diversity of structural connectivity elements and habitat resources (e.g. shrubs, tree canopy, grass, litter, and logs) for multiple dispersal guilds and faunal groups with the aim to create a mosaic of habitat types across the landscape
- prioritise management of key threats to biodiversity within core habitat nodes and along biolink corridors.

Biolink corridors identified in the connectivity study that should be considered for protection and enhancement are outline in Table 16 and Figure 8. A total of 48 individual priority corridors were

identified to link core habitats. These have been summarised into 16 separate landscape areas across the shire to aid in organising and coordinating works. Connectivity specifications by corridor type are provided in Section 9, with further information on improvements by habitat type, faunal group and barriers to connectivity presented in Appendix E.

Table 16. Protect and enhance connectivity priorities for existing biolink corridors in Cardinia Shire

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
1	1,2	1,2,3,4,5,6	Menzies Creek, Macclesfield Creek and Cockatoo Creek	Connectivity exists along the upper reaches of Menzies Creek, Macclesfield Creek and Cockatoo Creek which provides connections between Cardinia Reservoir, Wright Forest and forms a part of the broader Yellingbo State Emblems Conservation Area and linkages to remnant bushland on private land. **Management priorities:** • incorporate the management priorities identified in the Yellingbo State Emblems Conservation Areas (Victorian Environmental Assessment Council, 2013) • maintain existing coverage of habitat and structural connectivity elements throughout region including improving connectivity with Shepherds Creek and Pancake Creek to Cockatoo Creek in the west. • enhance connectivity for low-mobility species between Wright Forest and bushland to the north through additional of complex structural connectivity elements through the north-east parts of emerald and along the upper branches of Woori Yallock Creek. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas around Emerald and Cockatoo townships. Revegetation activities around these townships will be considered on a site-by-site basis.
2	3,4,5, 6,7	7,8,9,11, 12	Cardinia Reservoir	The outer vegetated perimeter of Cardinia Reservoir is an important corridor providing connectivity to numerous locations to the north, south, east and west of the reservoir. **Advocate management priorities including:** • maintain coverage of habitat and structural connectivity elements around reservoir and adjoining lands • enhance connectivity for low-mobility species along the southern perimeter of the reservoir, focusing on revegetation of public lands.

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				• Investigate opportunities to increase species movement through the reservoir security fence. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Upper Beaconsfield township. Revegetation activities around the township will be considered on a site-by-site basis.
3	8,9,10, 11,12	1,2,3,4,5,9, 10,13	Kurth Kiln Regional Park to Cardinia Reservoir	In the north, the corridor connects Bunyip State Park with Kurth Kiln Regional Park. These parks dominate the north-east corner of the shire and represent the most significant extent of intact core habitat acting as a large biolink node supporting the region. As a result, this interface-corridor is a critical dispersal asset which underpins landscape connectivity through the northern-most parts of the shire. To the west, the corridor continues from Beenak through to Cockatoo. This is an important corridor linking Kurth Kiln Regional Park to Cardinia Reservoir and provides habitat for a range of species. This corridor is particularly vulnerable around Pancake Creek with further investment recommended as a priority to increase the extent of native vegetation and add connectivity elements to the landscape. **Management priorities:** • maintain existing coverage of habitat and structural connectivity elements along the entire corridor • improve connectivity for low-dispersal species around Pancake Creek, focusing on increasing the extent of native vegetation and connectivity elements in the landscape. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Emerald and Cockatoo townships. Revegetation activities around these townships will be considered on a site-by-site basis.
4	13,14, 15	9,10,11,13, 18,19,21, 22	Cardinia Reservoir to Bunyip State Park	A multitude of linkages and smaller habitat patches were identified between Bunyip State Park and Cardinia Reservoir in and around Gembrook, Nar Nar Goon North, Pakenham Upper, Mount Burnett, and Dewhurst, with the RJ Chambers Flora and Fauna Reserve presenting a critical squeeze point. This corridor is the most important in the network due to the diversity of habitats, linkages and proximity to core habitat areas.

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				Furthermore, this corridor is likely to be the most significant linkage between the extensive forests and woodlands to the north-east of Cardinia Shire and the multitude of smaller parks and reserves in Melbourne's south-east (e.g. Churchill, Lysterfield, and the Dandenong Ranges). As a result, were this corridor to be further fragmented or lost, it has the potential to have a significant impact on biodiversity throughout the wider region. **Management priorities:** • highest priority for protecting regional connectivity • minimise all vegetation loss and ensure existing linkages, and the structural connectivity elements that underpin them, are maintained throughout the region • enhance vegetation with poor structural diversity • improve resilience through addition of structural connectivity elements throughout. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Emerald, Cockatoo and Upper Beaconsfield townships. Revegetation activities around these townships will be considered on a site-by-site basis.
5	16,17, 18	12,14,15, 16,34	Cardinia Creek to Cardinia Reservoir via Beaconsfield reserves	Cardinia Creek and vegetation throughout the Guys Hill and Upper Beaconsfield region act as important corridors linking Cardinia Reservoir to extensive areas of habitat to the south, including the Beaconsfield Nature Conservation Reserve and bushland on surrounding private properties. Furthermore, these corridors extend south into the urban growth corridor along Cardinia Creek and Officer Creek, eventually connecting with the Cardinia Creek parklands. Due to the need to consider bushfire risk these corridors are identified as 'conservation corridors,' with the direction that the quality of habitat is to be improved but not extended through large scale revegetation. The *Sub Regional Species Strategy for Melbourne's Growth Corridors and Growling Grass Frog Masterplan* provide guidance on implementing protection measures and investing in habitat creation and enhancement along the Cardinia Creek, Gum Scrub Creek and the area east of and including Toomuc Creek which are identified as areas of strategic importance for protection of the species.

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				Master plan actions identify areas within the future Cardinia Creek Parklands south of Princes Freeway as the priority solitary reach of creek line for investment in the region. This will include funding the establishment of approximately 10 habitat wetlands and enhancement works to be located along a 3.9-kilometre reach of the 'high' habitat creek line. A further 2.8-kilometre reach is identified to be protected to support the species along 'medium' priority habitat creek line. Melbourne Water have also prioritised this reach of creek line with a site-specific environmental management plan to compliment works in the Melbourne Strategic Assessment (MSA) area. The Cardinia Creek Peri-Urban Project is a multi-stakeholder group which has been enhancing habitat along Cardinia Creek in Beaconsfield and Guys Hill since the project conception in 2016. The Healesville to Phillip Island Nature Link community group have identified significant interest and have established community links with school groups along Cardinia Creek. It is therefore considered to be an important corridor connecting the north and south of the shire. While connectivity along these corridors was adequate for moderate and high mobility species, the modelling indicated poor connectivity for low-mobility species such as the southern greater glider. **Management priorities:** • continue to support the Cardinia Creek Peri Urban Project. • support Melbourne Water in their environmental management plan and investment priorities • support the Healesville to Phillip Island Nature Link community group and school groups in their habitat enhancement initiatives and educational opportunities • minimise further urban development and associated vegetation removal • remove barriers associated with roads • enhance connectivity for low-dispersal species through additional of structural connectivity elements. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Upper

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				Beaconsfield, Guys Hill and the urban growth corridor. revegetation activities around these townships will be considered on a site by site basis
6	19,20, 21	11,13,16, 17	Beaconsfield Nature Conservation Reserve to RJ Chambers Flora and Fauna Reserve	Large areas of adjoining bushland to the east of Split Rock Road provide an important corridor linking Beaconsfield Nature Conservation Reserve and surrounds with the RJ Chambers Flora and Fauna Reserve and extensive bushlands to the north and west, including Cardinia Reservoir. This corridor supports numerous patches of vegetation considered to be core habitat and is important for maintaining connectivity in a part of the landscape currently under pressure from increasing urban development. **Management priorities:** • minimise vegetation removal, with a focus on patches and connectivity elements on private land • remove barriers associated with roads. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Upper Beaconsfield township. Revegetation activities around the township will be considered on a site by site basis.
7	22,23, 24,25, 26	16,22,23, 24	Nar Nar Goon North to Beaconsfield Nature Conservation Reserve	Large areas of adjoining bushland to the east of Split Rock Road provide an important corridor linking Beaconsfield Nature Conservation Reserve and surrounds with the RJ Chambers Flora and Fauna Reserve and extensive bushlands to the north and west, including Cardinia Reservoir. This corridor supports numerous patches of vegetation considered to be core habitat and is important for maintaining connectivity in a part of the landscape currently under pressure from increasing urban development. **Management priorities:** • minimise vegetation removal, with a focus on patches and connectivity elements on private land • remove barriers associated with roads. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Upper Beaconsfield township. Revegetation activities around the township will be considered on a site by site basis.

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
8	27,28, 29,30	21,22,24, 25,26,27	Nar Nar Goon North to Tynong North	Two major corridors were identified from bushlands around Nar Nar Goon North to Tynong North and Bunyip State Park to the east. The northern corridor utilises multiple linkages through patches and connectivity elements around Back Creek and the northern edge of Maryknoll, while the second corridor skirts the southern edge of Maryknoll and utilising narrow linear patches and scattered connectivity elements to the north and south of Moore Road. While the landscape still retains a high cover of native vegetation and habitat, it is fragmented and linkages for moderate dispersal species is limited. Protection of existing habitat patches and connectivity elements along these corridors is important to prevent further fragmentation and loss of connectivity. **Management priorities:** • minimise vegetation removal, with a focus on patches and connectivity elements on private land • enhance connectivity through the addition of connectivity elements and habitat focusing on land around Ararat Creek and to the south of Maryknoll. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Maryknoll township. Revegetation activities around the township will be considered on a site by site basis.
9	31,32, 33,34	26,27,28, 32,33	Cannibal Creek including Tynong and Mount Cannibal	Cannibal Creek is a vital corridor linking core habitat associated with Bunyip State Park and the many small bushland reserves and properties throughout Nar Nar Goon North, Maryknoll and Tynong North with Mount Cannibal and the Bunyip River to the south-east. It is recognised a critical north-south corridor within the shire. While much of the creek line is vegetated, modelling indicates that connectivity for low and moderate dispersal species is poor. This may be due to the absence of canopy trees along parts of the corridor. Consideration should be given to improving the variety of habitat types (e.g. wetlands, scrub, woodland) along the entire length of the creek. The Cannibal Creek Catchment Biodiversity Project (CCCBP) has been operating since 2015 funding with eight key stakeholder groups to protect and enhance the creek line and surrounding

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				environments. This includes weed and pest animal works, revegetation, educational activities and fencing remnant vegetation. The project encompasses a 45 km^2 area along 12 kilometres of Cannibal Creek and includes private properties and nine different stakeholder groups. **Management priorities:** • continue to collaborate with the CCCBP in their environmental initiatives. • improve habitat diversity through addition of riparian woodlands or forest where absent. this may require widening the corridor to prevent encroachment on existing scrub or wetland communities • enhance connectivity between Cannibal Creek and Mount Cannibal through the addition of connectivity elements and habitat around Hamilton Creek.
10	35,36	28,29,30, 31	Bunyip State Park	Located in the south-east corner of Bunyip State Park, several linkages extending through Tonimbuk and along the hills to the south were identified as critical to providing connectivity between habitats in the south of the park. These corridors are important for mitigating the barrier effects of land clearance to the north of Tonimbuk which now separates the state park in this area. The southern corridor along the hills is important for providing connectivity to the south, including Mt Cannibal and Cannibal Creek, with a focus on high and moderate dispersal species. **Management priorities:** • protect and enhance vegetation along Shepherds Creek, Diamond Creek, Black Snake Creek and Dingo Creek and to the north, preventing further removal on private land. • enhance connectivity along the southern hill corridor through expanding and joining existing linear patches with the aim to create a continuous, connected patch. Focus on existing remnants at western end as a priority. • Conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Tonimbuk township. Revegetation activities around the township will be considered on a site by site basis.
11	37	32,40	Garfield South	A short but potentially important corridor was identified between the Princes Freeway the Garfield Golf Club to the south, utilising several

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				large patches to the north and west of Garfield. Linkages along this corridor are limited and while modelling indicates it currently supports connectivity for high dispersal species, it is tenuous due to a reliance on limited vegetation on private land. Furthermore, core habitat is fragmented and of a poor quality. This corridor may be critical to supporting the known population of southern brown bandicoot in the region. **Management priorities:** • where possible, enhance function of core habitat through infill plantings and appropriate land-use practices that limit habitat degradation. • enhance existing, narrow linear elements connecting habitat through complementary plantings and management, with a focus on private land to the south of the rail corridor. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Garfield township. Revegetation activities around the township will be considered on a site by site basis.
12	38	32,40	Bunyip	A single corridor was identified through the southern edge of the Bunyip township connecting core habitat to the north-east of the town with that to the south. Due to a requirement to traverse residential areas, this corridor is considered to provide limited connectivity for high-dispersal species only. Working within the utility functional needs, opportunities for protection and enhancement of connectivity exist within the rail reserve and Bunyip River drain to the south. This corridor may be critical to supporting the known population of southern brown bandicoot in the region. **Management priorities:** • prevent further loss of vegetation and habitat on the outskirts of Bunyip, with an emphasis on areas to the north-east, east and south. • protect and enhance connectivity along the rail corridor and Bunyip River drain to the south of Bunyip through improvement of habitat function and cover while maintaining utility functionality. • improve function of existing shelterbelts and linear elements on private land to improve

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				connectivity between core habitat and Bunyip River drain to south and east. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Bunyip township. Revegetation activities around the township will be considered on a site by site basis.
13	39,40, 401,42	39,40	Bunyip River	The Bunyip River and Yallock Creek corridors comprise of several large, narrow patches of scrub and unmanaged vegetation along the banks of (a) Bunyip River drain to the east and west of Cora Lynn and (b) from Bayles to Yallock Creek. Small patches outside of the drains within Bandicoot Corner and Bayles Fauna Park were identified along this corridor and act as significant habitat for the Southern brown bandicoot. Vegetation connectivity was disrupted for four kilometres between Cora Lynn and Bayles and along a 1.5 kilometre length of Yallock Creek. **Management priorities:** • protect the long-term permanency of habitat along the drain through appropriate land-management practices that provide habitat connectivity maintaining utility functionality. • prioritise linking existing habitat in the two locations where the corridors is interrupted • where possible, increase the width of linear patches utilising the adjoining road reserves or private land. • install suitable fauna bridges to allow movement of ground-dwelling mammals across waterways at regular intervals to connect habitat on either side.
14	43,44	36,37,38	Toomuc Creek south	This single corridor extends from the south edge of the urban growth area along the Toomuc Creek drain until it reaches Western Port in the south. It includes the multitude of drains and associated vegetation which joins the corridor as it runs south including, Cardinia Creek, Deep Creek and Gum Scrub Creek. At its southern end the corridor incorporates the lower reach of Bunyip River drain due to linkages along the East Gippsland rail reserve and the Western Port coastline. Along the southern-most extent of the drains, the corridor includes numerous large, linear patches of vegetation which are known to support important populations of the Southern brown bandicoot. Vegetation extent (width) and quality declines in the northern parts of the corridor.

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
				This corridor is considered critical as core habitat for a range of species, in addition to providing connectivity between the north and south of the shire. **Management priorities:** • work with Melbourne Water to find opportunities to protect the long-term permanency of habitat throughout the drain network through appropriate land-management practices which realise habitat opportunities while managing drainage functionality. • where possible, increase the width of linear patches utilising land between drains and along the adjoining road reserves or private land. • install suitable fauna bridges to allow movement of ground-dwelling mammals across waterways at regular intervals to connect habitat on either side. • enhance connectivity along the rail reserve and the South Gippsland Highway through complementary plantings to increase overall cover and function while maintaining utility functionality.
15	45	38, 41,45	Western Port Coastline	The Western Port coastline corridor is comprised of habitats associated with the intertidal zone and adjoining terrestrial communities along the southern edge of the shire. Primarily this includes mudflats, mangrove shrublands, coastal saltmarsh and estuarine flats grasslands. This corridor represents core habitat for many species which utilise the extensive intertidal zones of Western Port, including large numbers of threatened, migratory birds. Coordination of management efforts and funding arrangements to address the multitude of threats facing the coastal ecosystem is currently the major challenge facing this biolink. **Management priorities:** • develop coastal management plan to address issues facing the coastline environment. • establish coastline buffers to prevent impacts from adjoining land-use. Buffers should be sufficient to support multiple zones providing habitat for communities including mudflats, mudflats, mangrove shrublands, coastal saltmarsh, estuarine flats grasslands and coastal scrubs and woodlands.
16	46,47, 48	41,42,43, 44,45	Heath Hill to Adams Creek	Two corridors were identified in the far south of the shire linking Adams Creek Nature Conservation

Biolink landscape area number	Biolink corridor number	Biolink nodes to be connected	Areas to be connected	Details
			Nature Conservation Reserve	Reserve with bushland around Heath Hill in the east. Iorthern corridor relies on vegetation along the unused South Gippsland Rail corridor and the Lang Lang River, while the southern corridor utilises a variety of woodland fragments along roadsides and private property. While modelling only showed connectivity in this region for the southern brown bandicoot, these corridors are likely important for a range of species utilising the numerous small woodland patches through this region. **Management priorities:** • improve connectivity for moderate dispersal species along existing biolink corridors through the addition of structural connectivity elements with dense understorey vegetation. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around the Lang Lang township. Revegetation activities around the township will be considered on a site-by-site basis.

8.3.2 Connect

On the lower slopes immediately north of the Princes Freeway, and throughout the southern region and urban growth area, the focus will be on actions to 'connect' isolated habitats through the creation of new core habitat nodes and biolink corridors (comprised of a series of linkages connecting smaller patches and connectivity elements) in collaboration with the Municipal Fire Management Planning Committee.

The connect priorities recognise that the existing assets are insufficient to support a diversity of species and fauna groups and therefore the creation of assets is required through revegetation and regeneration of native vegetation to build species health and ensure Cardinia Shire's flora and fauna do not become locally extinct.

Precinct structure plans that have been or are under development within the growth corridor are critical in addressing the disconnect of vegetation in this area through the careful planning of waterway rejuvenation works, wetlands, open space, pathways and street corridors. Opportunities for highly mobile species could exist in urban landscapes by linking future environmental assets with existing waterways in a north – south direction and in an east – west direction via utility easements such as Pakenham Bypass, Princes Highway, the Gippsland rail reserve and transmission lines.

Storm water drainage designs inform the creation of retarding basins to be controlled by Melbourne Water within and around the growth corridors. Retarding basin assets are typically located along drainage lines and can be many hectares in area. They can provide an opportunity for significant conservation outcomes for riparian and aquatic habitats in addition to allowing the community to connect to nature.

The management priorities to 'create' future network connections will include:

- generate new core habitat nodes through the expansion and creation of habitat patches and connectivity elements
- create biolink corridors to connect existing or potential nodes, focusing on developing linkages based on existing connectivity elements
- improve connectivity for a diversity of dispersal guilds and faunal groups through the addition of structural habitat elements and resources (e.g. shrubs, tree canopy, grass, litter, and logs) in existing and proposed future core habitat nodes and biolink corridors
- removing or mitigating barriers to movement along current and proposed future biolink corridors including physical (e.g. fences) and non-physical (e.g. light, noise etc) barriers. Prioritise existing corridors and major barriers such as roads and waterways
- pursue broader landscape linkages beyond the study area guided by other local government and regional plans such as the *Regional Catchment Strategy* mapping and Melbourne Water priorities for ecological connectivity
- connecting with the Healesville to Phillip Island Nature Link project areas
- design revegetation corridors and model for fire risk to demonstrate no increased fire hazard.

Sixty individual future biolink corridors have been identified in the in the connectivity study that should be considered for creation. Table 17 summarises these corridors into eleven broad areas which are described in Figure 8 map and the biolink interactive mapping. Connectivity specifications by corridor type are provided in Section 9, with further information on improvements by habitat type, faunal group and barrier presented in Appendix E. The creation of safe landscapes that incorporates setbacks at a local property level and the creation of landscape scale fire breaks are outlined in Appendix F.

Table 17. Connect priorities for future biolink corridors in Cardinia Shire

Asset	Details
Pancake Creek	Several potential linkages were identified in the northern most part of the shire along Pancake Creek and Cockatoo Creek. Currently, both creek lines support a very narrow, and in places fragmented, cover of vegetation and provide limited connectivity for all but the most mobile of species. The corridor has the potential to provide regional connectivity from bushlands around Cockatoo to the south and Kurth Kiln regional park to the east, to Yellingbo Nature Conservation Reserve to the north. **Management priorities:** • in collaboration with Yarra Ranges Shire Council and private landholders, widen linear strips of vegetation along Pancake Creek, Cockatoo Creek (i.e. 'future biolink corridor' and Woori-Yallock Road through to Yellingbo Nature Conservation Reserve. • conservation management actions that do not conflict with protection measures will be prioritised in areas outside and around Cockatoo township. Revegetation activities around the township will be considered on a site by site basis.
Helios Camp to Bunyip State Park	A major weakness in the connectivity network in the northern region is the limited number of corridors between Bunyip State Park in the east and Cardinia Reservoir in the west. A potential additional corridor has been identified between Helios Camp and Shepard Creek through farmland. The corridor would utilise existing woodland and scrub elements along minor drainage lines and have a focus on moderate and high mobility species. **Management priorities:** • in collaboration with private landholders, widen and connect linear strips of vegetation between Helios Camp to the west and Shepard Creek to the east.
Cockatoo Creek	While limited core habitat existing along Cockatoo Creek, modelling indicated there was numerous connectivity elements that could be built on to provide connectivity for a range of species with moderate to high dispersal abilities. This would provide an additional corridor linking the extensive areas of habitat in the north-east (i.e. Bunyip State Park) with those in the north-west (i.e. Cardinia Reservoir, Wrights Forest and surrounds). Conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Cockatoo township. Connectivity must be cognisant to avoid revegetation within the conservation corridor linking into Cockatoo township. Revegetation activities around the township will be considered on a site by site basis. Due to the length of the creek, development of core habitat nodes of at least 5 hectares in size would be required at regular intervals (e.g. 1000m) to facilitate species dispersal. **Management priorities:** • in collaboration with private landholders, increase the cover and width of vegetation along Cockatoo Creek 'future biolink corridor', with a focus on canopy elements. • establish a 5-ha patch of woodland and scrub dominated vegetation roughly halfway along the corridor to facilitate dispersal between core habitats at either end.

Asset	Details
Cardinia Reservoir western perimeter	Based on the modelling, the presence of several large private landholdings that have been cleared, Wellington Road and the reservoir wall, has resulted in fragmentation and reduced connectivity along the western edge of the perimeter. While the modelling extended 500m beyond the edge of the shire, there may be sufficient connectivity in adjacent bushlands to mitigate this fragmentation and provide connectivity for a range of moderate and high-dispersal species. **Management priorities** • prevent any further removal of habitat and connectivity elements along this corridor. • in collaboration with private landholders, increase the cover and structural complexity of vegetation along Wellington Road. • consider options to lessen the barrier-effect associated with Wellington Road between Cardinia Creek Road and Muddy Creek, focusing on arboreal and ground-dwelling fauna. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Emerald and Upper Beaconsfield townships. Revegetation activities around these townships will be considered on a site by site basis.
Cardinia Creek to Beaconsfield Nature Conservation Reserve	While under increasing pressure from peri-urban development, the landscape around Guys Hill retains a relatively high cover of vegetation with the potential to provide connectivity between Cardinia Creek and Beaconsfield NCR. The highest cover of vegetation persists around residential developments connectivity must be cognisant of the avoidance of revegetation around Guys Hill and Upper Beaconsfield townships. Revegetation activities in these areas will be considered on a site by site basis. **Management priorities** • prevent any further removal of habitat and connectivity elements along potential corridors. • in collaboration with private landholders, increase the cover and structural complexity of vegetation that does not encroach on defendable space property setbacks.
Pakenham Upper	Several potential corridors have been identified around Pakenham Upper that would strengthen the regional network and provide connectivity between core habitat associated with Beaconsfield NCR in the east and Nar Nar Goon in the west. These corridors are focused on Toomuc Creek and Kitchen Creek on the eastern side, and Bourke's Creek Road and Shelton Road in the north. The northern corridor utilises several large patches of core habitat however these would need to be created to facilitate dispersal along the eastern corridor. **Management priorities** • in collaboration with private landholders, increase the frequency of connectivity elements between areas of core habitat along the northern route. • along the southern route, increase the cover and width of vegetation along creek lines, and identify potential locations which could be used to establish core habitat (i.e., a 5-ha patch of woodland).

Asset	Details
Princes Highway and East Gippsland rail line	While fragmented in places, the Princes Highway and East Gippsland rail line provide limited connectivity to species tolerant of the disturbances associated with road and rail activity. Investment in this corridor would provide an important east-west corridor linking the growth area to the Bunyip River in the east as well as facilitate connectivity between the north and south of the shire. Although this needs to be cognisant of ongoing development along these utility easements. The primary challenge associated with these corridors is the provision of core habitat at regular intervals along the routes. Given the heavily cleared landscape through which both the highway and rail line passes, this may need to be a long-term objective. **Management priorities** • identify opportunities within the road and rail corridors, with a focus on adjoining private land, to increase the cover and structural complexity of habitat. Focus initially on areas which intersect north-south corridors with connectivity to existing core habitat. • identify opportunities for the creation of core habitat (i.e. 3+ ha patches) at regular intervals (500-1000m) along the highway and rail line. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around Nar Nar Goon, Tynong, Garfield and Bunyip townships. Revegetation activities around these townships will be considered on a site by site basis.
Cannibal Creek to Tonimbuk	A series of potential north-south and east-west corridors were identified around Two Mile Creek that would improve connectivity between Tonimbuk, Bunyip State Park, Mount Cannibal and the Cannibal Creek corridor. This would significantly improve the redundancy of linkages between Cannibal Creek and the park, which is currently only connected along the upper reaches. The creation of these corridors would improve connectivity for a range of moderate and high dispersal species, including many small birds and mammals. **Management priorities** • increase vegetation cover and width along Two Mile Creek with a focus on connecting bushland areas to the immediate south. • investigate opportunities to widen and improve structural complexity along linear north-south corridors in the region (including vegetation within road reserves and on private land). • Conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around the Tonimbuk township. Revegetation activities around the township will be considered on a site by site basis.
Bunyip River drains	The southern region is bisected by a series of drains running to the north-east of Koo Wee Rup. These drains support a variety of vegetation types including endangered Swamp Scrub which are often fragmented or impacted by land management activities. Opportunities exist to work with Melbourne Water to realise habitat opportunities along drainage lines while still meeting drainage functionality. This could include investment to increase the cover of continuous vegetation and frequency of habitat patches along these waterways would significantly improve connectivity in the south of the shire and help to support isolated populations of wildlife, such as the Southern brown bandicoot. Key corridors include the following drains and associated road reserves and private land: Bunyip River Drain, Ten Mile Drain, Northern Boundary Drain, MacDonald's Drain, Seven Mile Drain, Yallock Outfall Drain/Creek, Southern Boundary Drain and central reaches of Deep Creek.

Asset	Details
	Bayles Fauna Park and Bandicoot Corner and associated bushland along the Yallock Outfall Drain has been identified as core habitat. This location is known to support populations of Southern brown bandicoots and should be the focus of future efforts to improve connectivity with areas of core habitat to the south of Koo Wee Rup and Bunyip River Drain to the north. **Management priorities** • work with Melbourne Water to find opportunities to protect the long-term permanency of habitat throughout the drain network through appropriate land-management practices which realise habitat opportunities while managing drainage functionality. Focus on improving the frequency of connectivity elements and the number and size of core habitats. • where possible, increase the width of linear patches utilising the adjoining road reserves or private land where possible. • install suitable fauna bridges to allow movement of ground-dwelling mammals across waterways at regular intervals to connect habitat on either side. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around the Bayles and Cora Lyn townships. Revegetation activities around these townships will be considered on a site by site basis.
Cardinia Creek drains	Several major creek lines converge into constructed channels in the south-east of the Shire. These include Cardinia Creek, Toomuc Creek and Deep Creek. These waterways have limited vegetation cover resulting in poor connectivity. Despite this, there are numerous small connectivity elements and areas of potential habitat that could be built upon to facilitate dispersal of more mobile species. The Cardinia Creek corridor is considered the priority for connectivity investment as the creek line to the north retains a relatively high level of connectivity through into the northern parts of the shire. To the south, the Cardinia Creek drain complex supports some of the largest patches of core habitat in the region. To the east of Cardinia Creek, Toomuc Creek and Deep Creek represent important urban corridors bisecting the growing townships of Officer and Pakenham. While habitat is limited within the urban growth area, they have the potential to provide important connectivity between the north and south of the shire. The *Growling Grass Frog Masterplan* identifies 'high' 'medium' and 'low' priority habitat areas to be set aside along the Gum Scrub and Toomuc Creek Corridors south of Princes Freeway through the precinct structure planning process. The GGF Masterplan will act as a catalyst for connectivity in these precincts and become a focus species to engage the community in their local natural environment. Melbourne Water regional retarding basins could compliment these habitat opportunities. Opportunities exist to extend these corridors into green wedge areas on private land and realise linkages through utility corridors such as the powerline easement and Princes Freeway **Management priorities** • increase the cover and width of vegetation along creek lines, utilising the adjoining road reserves or private land where possible. • Improve structural complexity along corridors by introducing additional swampy woodland elements (e.g. swamp gums).

Asset	Details
	• identify opportunities for the creation of core habitat (i.e. 3+ ha patches) at regular intervals (500-1000m) along the creek lines. • conservation management actions that do not conflict with asset protection measures will be prioritised in areas outside and around the Urban growth corridor. Revegetation activities around the Urban growth corridor will be considered on a site by site basis. • along drainage lines work with Melbourne Water to find opportunities to protect the long-term permanency of habitat throughout the drain network through appropriate land-management practices which realise habitat opportunities while managing drainage functionality
Lang Lang	The existing unused rail reserve and South Gippsland Freeway provide excellent opportunities for linking the existing corridors and habitat around Koo Wee Rup with that to the south around Lang Lang. The creation of connectivity elements and small areas of core habitat would facilitate movement of more mobile species and importantly link known populations of southern brown bandicoot. This corridor is considered a priority for the region. A potential additional corridor to the north connecting core habitat around Bayles with the Lang Lang river is proposed to further improve landscape-scale connectivity. This corridor will require substantial investment in the creation of core habitat and connectivity elements on private land adjoining the narrow road reserves and should therefore be a long-term objective. Several smaller corridors are proposed to the east of Lang Lang to connect numerous large bushland patches around Heath Hill and Lang Lang East. These corridors are focused on expanding existing habitat and connectivity elements along the Lang Lang River and Little Lang Lang River. **Management priorities** • increase the cover and structural complexity of habitat along the South Gippsland rail line and freeway, utilising adjoining private land where possible. Identification of locations suitable for the creation of core habitat (i.e. 3+ ha patches) will be required to facilitate dispersal. • in consultation with private landowners, create corridors for moderate and high dispersal species to the east of Lang Lang through the increasing the frequency and complexity of connectivity elements. • identify suitable locations for the creation of core habitat along Little Lang Lang River and Lang Lang River. • investigation long-term options for the creation of a corridor between Lang Lang River and Bayles. • conservation management actions that don't conflict with asset protection measures will be prioritised in areas outside and around the Lang Lang township. Revegetation activities around the township will be considered on a site by site basis.

8.3.3 Engage and educate

This plan and associated mapping provides an essential tool to focus community, government and non-government conservation goals over the coming decades. The mapping can act as the catalyst for conversations with multiple stakeholders to determine the key strategic areas that will enhance biodiversity. The ability of this plan to engage land holder groups to work together enables a superior conservation outcome compared to solitary land managers acting individually. This is demonstrated in the current multi stakeholder projects of Cardinia Creek Peri Urban Project and the Cannibal Creek Catchment Biodiversity Project.

Furthermore, the mapping provides a wealth of opportunities to engage property owners who aspire to connect their properties to biolinks by identifying the most valuable environmental areas at each individual property. Valuing nature through community education and engagement is a fundamental step to realising this plan's goals to improve ecological connectivity across Cardinia Shire's urban and rural landscapes. Local community Friend's groups and Landcare groups activities periodically uploaded onto the biolink plan mapping which will increase group exposure to the broader community and likely lead to greater community participation. In an iterative process enthusiasm for an alternative biolink corridor could inform newly mapped different corridor locations. A biolink communication plan will also focus on increasing internal Council staff, community and stakeholder engagement and education in the plan.

In summary through stakeholder engagement this plan will inform conservation planning and actions in support of and relating to:

- internal Council expenditure and allocation of priority project areas and initiatives
- priority areas for collaboration with government departments and organisations such as Parks Victoria, Melbourne Water, CFA, Western Port Biosphere, Regional Catchment Strategy priorities
- community group projects, including the Cardinia Environment Coalition, friends groups and Landcare networks, Southern Brown Bandicoot Regional Recovery Group
- providing a focus for external grant applications
- focusing goals for residential property plans
- targeted university research opportunities
- focusing school and education groups conservation programs
- assessing adaptation options to protect strategic biodiversity habitats and support the resilience of climate-threatened ecosystems and species
- targeting suitably eligible land holders within biolink corridors on the opportunities of the Native vegetation credit register scheme ant Trust for Nature covenants.

The prioritisation analysis project (refer section 10.5) provides additional high-resolution mapping of biodiversity priority areas at an individual property scale. This additional resource can inform the optimal locations for conservation works and is available on the publicly available biolink mapping portal.

While the Municipal Fire Management Planning Committee (MFMPC) will inform planting design and the incorporation of strategic fire breaks for large scale revegetation projects, landholders need to be assisted to understand the actual bushfire risk associated with revegetation programs and remnant vegetation management (as opposed to perceived risk). CFA resources identified in Appendix F, text in Section 9.3.2, the draft Cardinia Shelterbelt Design Guidelines and Cardinia's Safer together – Private Fuel Management Project provide bushfire property preparation information to treat the risk in a way which, wherever possible, minimises harm to both people and the environment.

Council's community education initiatives such as the Deep Creek Ecocentre, Gardens for wildlife program and Landcare grants seek to engage and educate the community so that residents value biodiversity. Citizen science opportunities represent an important opportunity for the community to both interact with nature while also provide highly valuable data on the location of commonly observed indicator species (refer section 6) to support assessments of biodiversity health over time. Limitations do exist with this to survey method for less common species or species which are difficult to survey. Council reserve audits offer an opportunity to extensively survey for cryptic species which require technical surveying expertise, although the Council reserve system is limited in its extent across the shire. Partnerships with universities will fill the gap to monitor indicator species throughout the shire which require scientific expertise. Appendix M summarises the efficacy of monitoring programs for each of the indicator species.

The action plan identifies ten actions and compliments 17 existing environmental actions to support the community to enhance and monitor Cardinia Shire's natural environment.

There is growing recognition of both the value of and need for Indigenous knowledge in natural resource management. Regular collaboration with Traditional Owner groups identified in Council's *Biodiversity Conservation Strategy* and associated action plan enables Council to build a relationship to facilitate opportunities for:

- cultural education
- knowledge sharing and training in traditional land management techniques
- participation in strategic precinct structure planning
- participation in strategic conservation planning and on ground management
- recognition of sites with cultural heritage significance
- education to recognise sites of cultural importance.

Indigenous participation and collaboration in land management activities, such as cultural burning and the ecological benefits of cultural burning are well recognised in scientific literature (Gott, 2005) (Morgan, 2020). The action plan identifies an action to explore the use of Traditional Owner 'cultural fire practise,' burning.

Within the urban growth corridor and township areas a focus on highly mobile species including birds, lizards, insects and native plants is recommended to promote an understanding of the importance of vegetation connectivity within Cardinia Shire's urban and township communities. This will help to develop a greater appreciation of the importance of biodiversity and connectivity within these built environments. Council reserve master plans, nature strip policy and open space plans provide an opportunity to contribute to the mapped biolinks and future urban biolinks by being sympathetic to these conservation outcomes within the plans' goals.

9 Biolink design principles

The on-ground implementation of management priorities will be heavily influenced by a range of factors, including land tenure and use, existing management practices, the nature and extent of vegetation and the target species connectivity requirements.

Several land use contexts have been identified within the shire that commonly support, or have the potential to support, connectivity elements and facilitate movement through the landscape. These include:

- shelterbelts on private land
- constructed drains and channels, primarily in the south of the shire
- natural watercourses and associated riparian communities, primarily in the north of the shire
- vegetated road and rail reserves
- utility easements.

While the primary purpose of biolink corridors is to increase connectivity of flora and fauna across the landscape, Council advocates for the creation and management of biolink assets that are safe to people and property. This relates to the management of bushfire risk at both landscape and local scales. This plan provides a focus for conservation outcomes in rural and green wedge locations that make up approximately 92% of the shire rather than the urban growth corridor and townships. The focus of conservation efforts away from settlement areas:

- reduces the competing land use goals of asset protection and vegetation enhancement
- enables more diverse habitat opportunities to be realised for low, moderate and high mobility species which require structurally complex and diverse vegetation types more suited to larger parcels of land.

The following section provides general management principles, specifications for common connectivity elements, in addition to guidance relating to fuel management designs for biolink corridors in bushfire prone areas.

9.1 Management principles

When considering actions to improve connectivity, the following principles should first be considered and addressed where applicable:

1. Overarching management principle; where there is a conflict between proposed voluntary conservation works and an increased bushfire safety risk to people and property the management direction must always accede to not increase the risk to people and property as a result of the new works beyond acceptable levels as defined by the Municipal Fire Management Planning Committee. Four practical examples to demonstrate the implementation of this management principle include:
    a. Where a 150me bushfire site assessment area exists or is created within an existing biolink corridor no new revegetation works will be proposed within this area. Isolated and spatially distant planting may be considered on a site-by-site basis which is specified in Appendix F1 and depicted in the cross-section Figure 10.
    b. Where the Municipal Fire Prevention Planning Committee are unsatisfied that a proposed revegetation project does not satisfactorily manage the risk to people and property then the project cannot proceed (refer Sections 9.3.1 landscape scale biolink planning and section 10.4 decision support matrix to implement safe biolinks).
    c. The identification of conservation corridors in populated areas, which designates no large- scale revegetation within these biolink assets.
    d. This plan informs the location and best practise widths for biolink corridors in terrestrial areas and along waterways. Where a future settlement proposal within a zoned Rural zone area conflicts with a proposed biolink corridor, a separate assessment report will be

commissioned to define the extent of the biolink and the interface with proposed development.

2. Focus on priority locations
   - areas of core habitat and connectivity elements along biolink corridors should take precedence.
3. Identify target species
   - understand the species for which connectivity is limited and could realistically be restored. This includes identifying and prioritising under-represented or poorly connected habitat types.
4. Functional connectivity
   - identify functional improvements to existing habitats and connectivity elements that could be made to improve connectivity (e.g. improve structural complexity or availability of food resources).
5. Minimise threats and barriers
   - consider the impacts of existing threats and barriers in the landscape, including pest animals and weeds, roads and human activity. Address land use which may result in the degradation of existing habitat or connectivity elements.
6. Increase extent
   - consider opportunities to expand, connect or infill existing habitat and connectivity elements to increase the extent and quality of habitat across the network.
7. Build resilience
   - invest in multiple linkages and corridors to build connectivity between areas of core habitat and ensure redundancy within the connectivity network.
8. Engage and educate
   - support actions through education programs to ensure long-term engagement of key stakeholders.
9. Monitor and review
   - ensure actions are reviewed, and threats and management issues addressed to ensure investments achieve long-term outcomes.

While modelling has used high resolution mapping and officer knowledge to determine the locations of biolink nodes and corridors, ongoing site assessment of the vegetation habitat quality is important to understand the suite of conservation management opportunities that can be implemented for each specific area. Site assessment of vegetation quality using for biolink nodes and corridors using 'rapid habitat assessment' can be uploaded to the biolink mapping over time. This will provide information on the priority areas within the biolink that require management action.

On ground conservation management actions to either protect and enhance or create new bioinks can be summarised in following seven opportunities to improve species habitats. These are identified in Table 18.

Table 18. Conservation management actions available to support native species

Conservation management type	Habitat improvement type	Examples
Pest plant control	Threat abatement	Management of high priority invasive weeds that displace native plant habitat
Pest animal control	Threat abatement	Management of high priority invasive animals that predate native fauna or destroy native flora
Protection fencing	Threat abatement	Removal of grazing herbivores (i.e. stock or deer) to protect habitat for native flora and fauna
Revegetation	Habitat connectivity	Planting of ground storey, shrub and tree plant strata
Stimulating natural ecological processes	Habitat enhancement	Ecological burning or altering water hydrology
Artificial habitat creation	Habitat connectivity	Habitat boxes, shelter refuges, frog ponds, amelioration of roadside barriers (rope bridges and underpasses), traffic awareness signage
Community awareness programs	Community education	Awareness raising and education programs to increase community understanding of the natural environment

The choice of the suite of conservation management actions that can be implemented at a project site to protect, enhance or create biolinks will be dependent on the opportunities and constraints which are specific to each project location. Prior to commencing a biolink project a site assessment must be undertaken with the land manager to understand these site features which are summarised in Table 19. Responses to the site assessment could include altering the design of habitat improvement works to best respond to the local conditions and landowner needs.

Table 19. Project site features that will inform the choice of conservation management actions employed to enhance biolinks

Site features which present as opportunities for conservation management actions	Site features where selected conservation management actions and outcomes may be constrained or limited
Land features (i.e. slope, vegetation type)	Specifics of the conservation threat (pest plants, animals, habitat deficiencies)
Location of threatened vegetation communities	Land zoned without conservation or a sustainable land use outcome defined within the primary purpose
Presence of threatened flora and fauna	Proximity to areas defined as Bushfire prone and landscapes within the Bushfire management overlay
Proximity to waterbodies, drainage lines, native vegetation and consolidated areas of vegetation	DELWP modelled bushfire risk areas
Proximity to conservation areas	Proximity to township settlements and populated areas

Site features which present as opportunities for conservation management actions	Site features where selected conservation management actions and outcomes may be constrained or limited
Land zoned with a primary purpose zoned for conservation	Location to individual property asset protection zones
Cost and efficacy of the project works	Value of agricultural land
Community interest and support	Current and future development proposals
Collaborative opportunities with government organisations (Melbourne Water, DELWP, Parks Victoria, CFA, Fire Rescue Victoria)	
State conservation management initiatives (i.e. Strategic management prospect mapped areas, sites designated within the Melbourne Strategic Assessment, state funded programs	
Location of mapped biolink priority areas (i.e. defined nodes and corridors)	
The need to ameliorate climate change impacts or hazards such as salinity, land slip, acid sulphate soils and land attenuation	

9.2 Species requirements

Critical to the concept of connectivity is understanding the ability of a species to use features within the landscape to facilitate movement. To do so we need to understand 'structural connectivity', which are the physical structures which act as stepping-stones or pathways through and landscape. These may, include vegetated road reserves, overgrown drainage lines or shelter belts, as well as more subtle habitat elements such as scattered trees or shrubs, or even clumps of tussock grass or coarse woody debris. Functional connectivity builds on structural connectivity and refers to the degree to which movement and dispersal occurs for a given species or guild (i.e. connectivity) and takes into account the ecology and behaviour of the animals when interacting with structures and landcover (Doerr et al. 2014).

Improving structural connectivity, either through the creation or enhancement of habitat, is one of the most effect ways of improving connectivity within a landscape. Guidelines for the creation and enhancement of habitat and structural connective elements for common dispersal guilds is provided in Table 19 and Table 20. Functional connectivity improvements for species are elaborated on in Appendix E. An example of structurally complex habitat with associated connective elements is provided in Figure 9.

Figure 9. Cross section of structurally complex habitat with associated connectivity elements

9.3 Connectivity specifications

The following sections provide general habitat and connectivity specifications for common areas of vegetation connectivity that exist within the shire. These specifications need to be considered in the context of the broader biolink corridor and multiple management priorities such as the requirement to create safe landscapes for people and property, provision of agriculture, industry and critical infrastructure.

9.3.1 Landscape scale biolink planning and fuel management

The creation and management of biolinks that are safe to people and property is identified in the goals of this plan alongside the need to increase connectivity for flora and fauna across the landscape.

To enable this outcome at a landscape scale the Biolink Plan supports the goals identified in the *Municipal Fire Management Plan* (MFMP) and the *Metropolitan Bushfire Management Strategy* (MBMS).

This plan is consistent with the MFMP and MBMS outcomes in the following ways:

- the exclusion of terrestrial biolink corridor initiatives from all major townships defined as ‘extreme’ or ‘very high risk’ asset areas which are identified as areas of greatest asset loss in the shire
- the identification of conservation corridors along waterways and high-risk areas within townships and settlements which aim to enhance habitat for species connectivity while not increasing the extent of riparian vegetation
- avoidance of biolink corridor planning from all ‘strategic’ and ‘tactical’ fire access roads
- identification of MBMS Bushfire Risk Engagement Areas [program] which provides the ability for Council and fire management authorities to talk about holistic land management outcomes during community liaison. This can include realising multiple property outcomes such as the protection of people and property as a priority in addition to cultural heritage outcomes and biodiversity and ecosystem resilience
- alignment of strategic fuel reduction works with Department of Environment, Land, Water and Planning (DELWP) Code of Practice for Bushfire Management on Public Land (2012). Biolink assets do not conflict with the public land bushfire risk asset management zones. Synergies exist where biolinks intersect with ‘Landscape management zones’ as these zones have the dual goal of reduction of bushfire hazard while supporting ecological resilience.

Biolink corridors have been individually reviewed to exclude each dwelling and building 150 metre bushfire site assessment area (refer Section 8.1 regional priorities). No structural and functional revegetation of biolink corridors are proposed within the 150 metre assessment area (refer Section 9.3.2 property scale biolink planning). This significantly contributes to bushfire risk reduction at a landscape scale.

Projects to increase the extent of biolink corridors will be informed by the DELWP bushfire risk modelling analysis. The modelling will provide information on the impact to assets because of increasing the extent of the biolink corridor. The risk modelling considers vegetation extent, fire history (fuel loads since last fire), flame height at a fire danger index of '130', house loss probability, fuel type, and ember attack. Results will determine if increasing the biolink corridor extent will either increase risk or have no impact to the surrounding landscape. All landscape scale revegetation proposals will include the results of the risk analysis in the 'Revegetation - vegetation protection bushfire risk site assessment' which will be reviewed by the MFMPC (refer Section 10.4 decision support matrix).

Site specific vegetation management treatments and installation of fuel reduced areas and fire breaks will be determined using the expertise from the MFMPC for each individual project. Landscape scale fire events can significantly impact biodiversity by destroying large areas of habitat and multiple biolink corridors in a single episodic event. Through collaboration with the MFMPC the strategic design of fire breaks within a biolink corridor a suite of fuel management works to enable fire suppression could be deployed during a bushfire event. Refer to Appendix F2 for the options to manage fuel loads along strategic fire breaks. This could include targeting areas where they cross strategic and tactical fire access roads and complementary fuel management treatments on adjacent private land. This will also require collaboration with local CFA brigades.

The benefits of designing fuel reduced zones within a biolink corridor includes:
- providing support for asset protection
- provide areas which assist in making fire suppression safer and more effective
- provide a barrier to the spread of bushfire by reducing its speed and intensity
- reduce speed from predictable high consequence ignition areas
- building resilience of the biolink corridor from the threat of a future fire.

Fuel management objectives within a fire break need to be considerate of species mobility requirements as identified in Table 9. The most restrictive species mobility requirements include:
- maximum gap crossing distance of 75 metres and habitat patch sizes of 10 hectares for greater glider possums in Cardinia hills and forests
- maximum gap crossing distance of 100 metres and habitat patches of 3 hectares for the southern brown bandicoot in the Cardinia Shire flats.

These measures represent the limits that a suite of low mobility species can travel. For sustainable movement of species, where practically possible, more conservative habitat thresholds should be applied to ensure that vegetation is sited closer together and vegetation patches are larger in size. Through incorporation of species mobility needs in the design of fuel managed zones within a biolink corridor, both fuel management goals and environmental goals can be realised within an individual corridor. This is represented in Section 10.6 under management responses and implementation.

Council's current fuel reduction program targets strategic fuel reduction along strategic and tactical access roads. Vicroads roadside maintenance regimes are limited to available funding which enables 3-4 metre mown vegetation setback and the removal of dead wood and tree weight reduction. The principle of coordinated fuel management on private and public land including roadsides is supported by the MBMS.

Where a strategic fire break is viewed as critically important as part of a biolink proposal and is located on private land Council and fire management agencies may require a level of assurity that

the fuel management goals would be realised on site for the biolink to proceed. This could include an agreed maintenance schedule or on title agreement to manage the land to maintain the reduced fuel level.

Novel fuel management opportunities have been identified in the biolink action plan including investigation of a framework to facilitate ecological and fuel reduction burning on private land and the investigation of cultural fire practise burning by traditional owners. This initiative is also supported by the MBMS. Issues of risk and liability are important to resolve for these opportunities to be realised. The action plan also identifies the establishment of demonstration biolinks to assess the effectiveness of fuel management features which will inform the design of future biolink corridors. Refer to Section 10.6 for detail of typical demonstration corridors.

Future opportunities exist where Council can utilise evolving computer fire behaviour modelling to assess how fire prevention works can be programmed within a biolink corridor. The latest evolution in computer modelling enables higher resolution fuel load assessments (30 x 30 metre grids) to be assessed within the model. While outputs are at a 90 x 90 metre grid. Significant data collection of fuel loads across a project area would be required to enable the model to accurately predict fire behaviour. Where this technology is available this could enable assessment of bushfire risk as a result of proposed biolink corridors.

The likelihood of a bushfire starting and its rate of spread and intensity in a riparian area will depend upon the presence of an ignition source, fuel, topography and weather. The relative degree to which fuel, topography and weather will determine fire behaviour and its impact will vary from site to site. Well managed riparian vegetation with limited grass and weed growth and low slopes, and under a Low to Moderate Fire Danger Rating, bushfire may be difficult to ignite and may only burn very slowly and at a low intensity (DELWP, 2017). As the amount of riparian land is limited, compared with other land uses, riparian land which typically extends over narrow corridors can be expected to have only a limited influence on bushfire spread at a landscape scale. In addition, if spotting is limited, a fire burning in a forested riparian area is expected to be slower and therefore less likely to contribute to fire spread at a landscape scale than a fire burning in grass or crops and is not expected to generate sufficient updraft to carry embers far (DELWP, 2017).

Not all vegetation will pose a threat to assets. Trees can filter radiant heat and embers as well as reducing wind speed and the rate of spread and intensity of fire. In addition, revegetation proposals which involve creating narrow vegetated strips which are remote from assets, may not significantly add to bushfire threat from radiant heat. (CFA, 2017)

Superb lyrebird project

Within forested habitats that support the superb lyrebird (Menura novaehollandiae) an opportunity exists where the protection and enhancement of this species can provide a positive benefit for fuel reduction which will influence fire behaviour to support the creation of safe landscapes for people and property.

The superb lyrebird has been recorded as being the most significant terrestrial ecosystem engineer on the planet. Studies have shown that on average, lyrebird foraging reduced litter fuel loads by 25% (1.66 t ha^{-1}). Fire-behaviour modelling showed that lyrebird foraging led to a lower likelihood of fire occurring and less intense fire (Nugent, Leonard, & Clarke, 2014).

Foraging activity of Lyrebirds was also studied in Sherbrooke Forest and Powelltown which found that for a population density of 0.3 lyrebirds/ hectare, Lyrebirds displaced on average 155 tonnes/ hectare of litter and soil over a 12-month period. Leaf litter was also reduced by almost three times in the area where Lyrebirds were active. (Maisey, Haslem, Leonard, & Bennett, 2020).

Lyrebird foraging could likely to affect forest fuel loads and hence fire behaviour in habitats that it could be found in and around Upper Beaconsfield, Emerald, Cockatoo, Upper Pakenham, Garfield North, Kirth Kiln, Tonimbuk and Gembrook. The support of habitat for the species which could directly influence fire behaviour would include actions such as:

- support corridors of known populations identified in priority biolinks (refer to Section 8) to provide habitat connectivity
- prioritise targeted fox control within known populations of the species.

The use of the prioritisation matrix (refer to Section 10.5) can inform optimal locations to deploy a pest animal program for the species which should follow the guidelines set out in the *Eastern Region Pest Animal Strategy*.

The biolink action plan has identified an action to measure fuel loads through a lyrebird habitat support program which will include targeted fox control.

9.3.2 Property scale biolink planning and fuel management

Council and government public reserves are scattered throughout the landscape and alone are insufficient to sustainably support native species. Modelling has identified that habitat connections through private properties are a fundamental component to the preservation of native species. Biolink corridors that provide functional and structural habitat can provide this connectivity for species. By implementing conservation management actions defined in Appendix E (functional connectivity improvements), private properties will contribute to the preservation of our native species which is of benefit for the broader community. Residents also benefit through the ecosystem services that native species provide (Costanza, 1997) and are able to better value our natural environment through the incidental contact they experience with native species

At a property scale, fuel management outcomes must be considered to ensure revegetation does not increase bushfire risk to people or property. This can be achieved through Whole Farm Planning and the identification of zones for the location of the dwelling, defendable space, agriculture and conservation outcomes.

Property planning can consider many factors such as soil type, problem area of erosion, salinity and landslip, remnant vegetation prevailing seasonal winds the need for shade the location of property infrastructure and agricultural areas and other on-site specific features.

Key steps in property planning are summarised as:

- conducting a property assessment
- conducting a landscape assessment
- determining property objectives
- creation of a plan that sets out the locations for property features including dwelling setback zones for vegetation management
- implementation of plan
- monitoring and maintenance.

Conservation works such as pest plant control and pest animal control can enhance biodiversity and reduce biomass (refer Section 9.3.1). Activities such as excluding grazing from remnant vegetation and large-scale revegetation could increase biomass which will influence bushfire behaviour. This plan advocates that all conservation activities at the property scale must consider their influence of fire behaviour on people and property and must be considerate of vegetation setbacks from dwellings and buildings.

This plan supports the establishment of a 150m bushfire site assessment area from buildings and dwellings (refer Section 8). Large scale conservation opportunities including revegetation are proposed to be considered outside of the 150m assessment area. Within the assessment area fuel management priorities are the priority to ensure people and property are protected from bushfire hazard. Figure 10 describes three areas to achieve conservation and fire safety outcomes including:

- an inner defendable space area. Depending on the house age this is defined in the planning scheme in clause 52.12 (Bushfire protection exemptions) or 53.02 (Bushfire planning), which identify specific setback distances and vegetation management guidelines – refer Appendix F1
- the bushfire site assessment area extending 150m from the dwelling
- biolink corridor providing functional and structural habitat for species outside of the 150m assessment area.

Within the 150m bushfire site assessment area there are opportunities to achieve multiple objectives of managing bushfire behaviour while also realising limited conservation outcomes. This can be achieved through careful design and selection of plants.

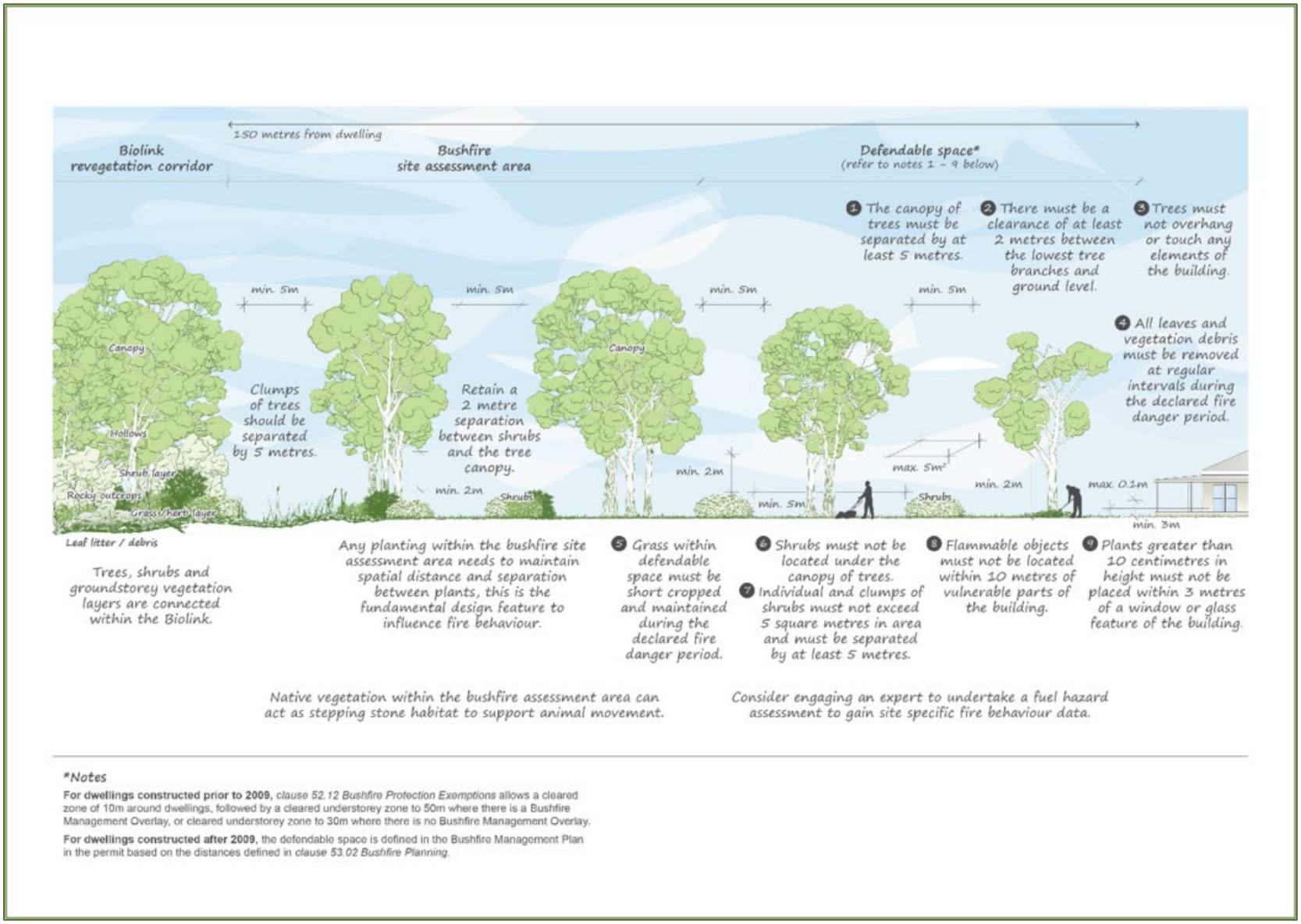
This plan advocates for the provision of ‘steppingstone’ habitat for high mobility species within the property 150m assessment area by designing plantings which are isolated and spatially distant as described in Figure 10. Noting that spatial separation of plants is the primary factor to influence bushfire behaviour rather than species selection. Planting specifications within the bushfire site assessment area need to be considered on a site-by-site basis and include the principles identified in Appendix F1 ‘Opportunities to create safer landscapes.’ Professionals in bushfire risk assessment can provide site specific fire behaviour analysis to guide plant design.

The CFA have developed vegetation assessment and design guidelines that consider bushfire planning principles and can be utilised for property planting close to assets. The documents include:

- CFA Riparian land and bushfire. Resource document version 2. (2017) (refer Appendix K and L)
- CFA Landscaping for bushfire. Garden design and plant selection (2011).

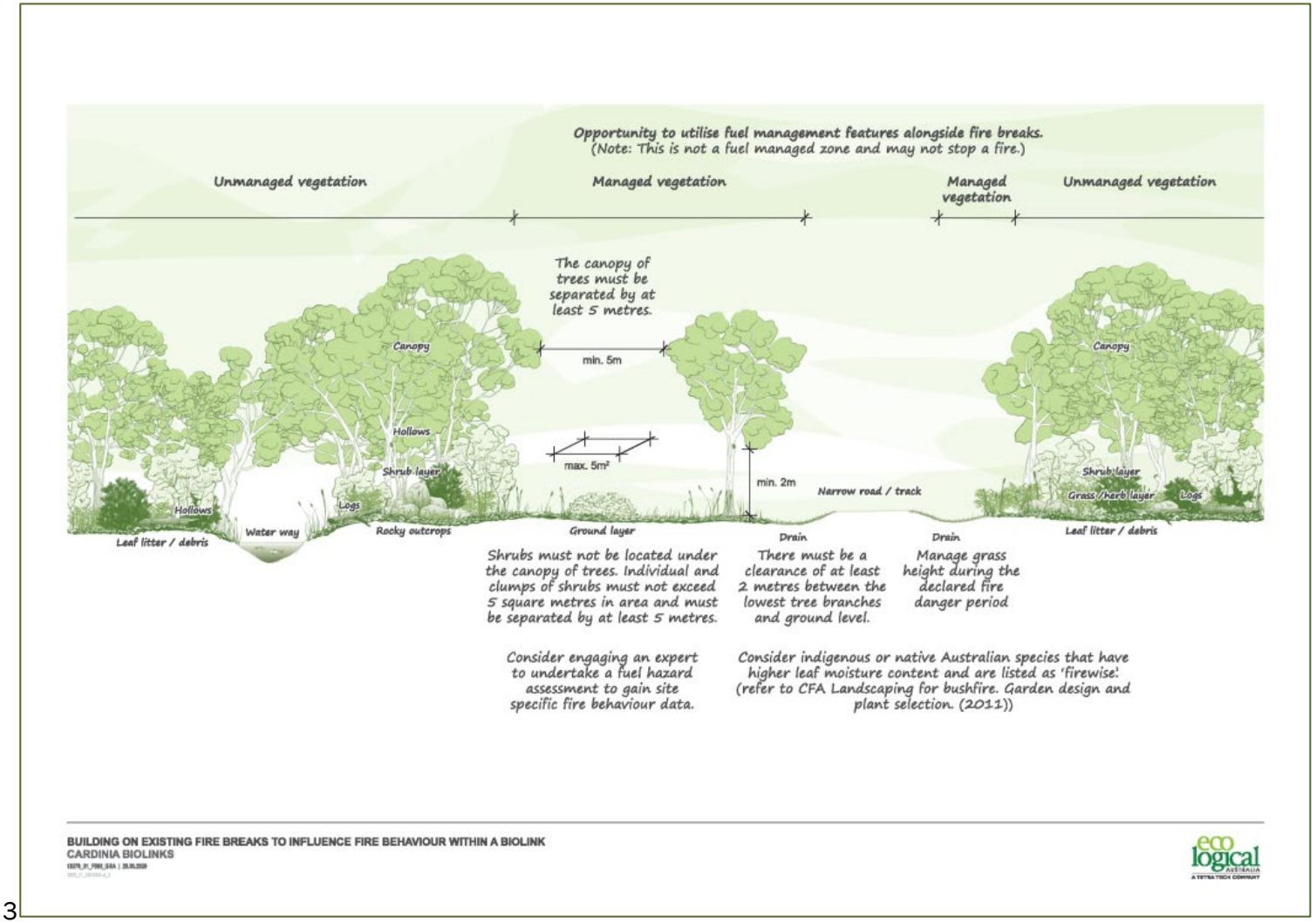
While all plants will burn, the use of ‘fire wise’ plants (refer CFA Landscaping for bushfire, 2011) also provides landowners with an additional tool to manage bushfire risk within the 150m assessment area.

Figure 10. Bushfire assessment area adjacent to a biolink revegetation corridor



A fuel managed area can also be incorporated within a biolink corridor. This could include utilising an existing internal property track or dam. Building these features within a planted corridor could influence fire behaviour for a lower to moderate intensity fire. A cross-section diagram illustrates this design in Figure 11.

Figure 11. Fuel management features along a fire break



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Some rural properties view the entire property as an asset. Utilising expertise from fire services, bushfire property plans may need to be developed to manage perceived and actual fire risks from revegetation projects. Revegetation could also be required to ameliorate other land management issues such as salinity, land slip, erosion and acid sulphate soils.

An opportunity exists to align biolink corridors with the Victorian Government's native vegetation credit register scheme which can also yield a financial payment to landholders. The scheme involves offsetting the loss that has resulted in the removal of vegetation in one location with finding environmental gains in a second location. Offset owners secure and manage offset sites to improve native vegetation condition. This represents a significant opportunity to realise offset sites within biolink corridors with a mutually beneficial financial and environmental outcome for landholders. Similarly, the biolink corridors also assist in targeting resources to recruit new Trust for Nature properties to permanently protect vegetation on title.

9.3.3 Township areas

Within rural townships the Biolink Plan supports the protection of people and property through risk-based planning as the priority land management goal in these locations. This involves managing surface, near surface, elevated and bark fuels within and around rural townships to manage fuel loads to influence fire behaviour. Township areas that were excluded from terrestrial biolink corridor priorities includes:

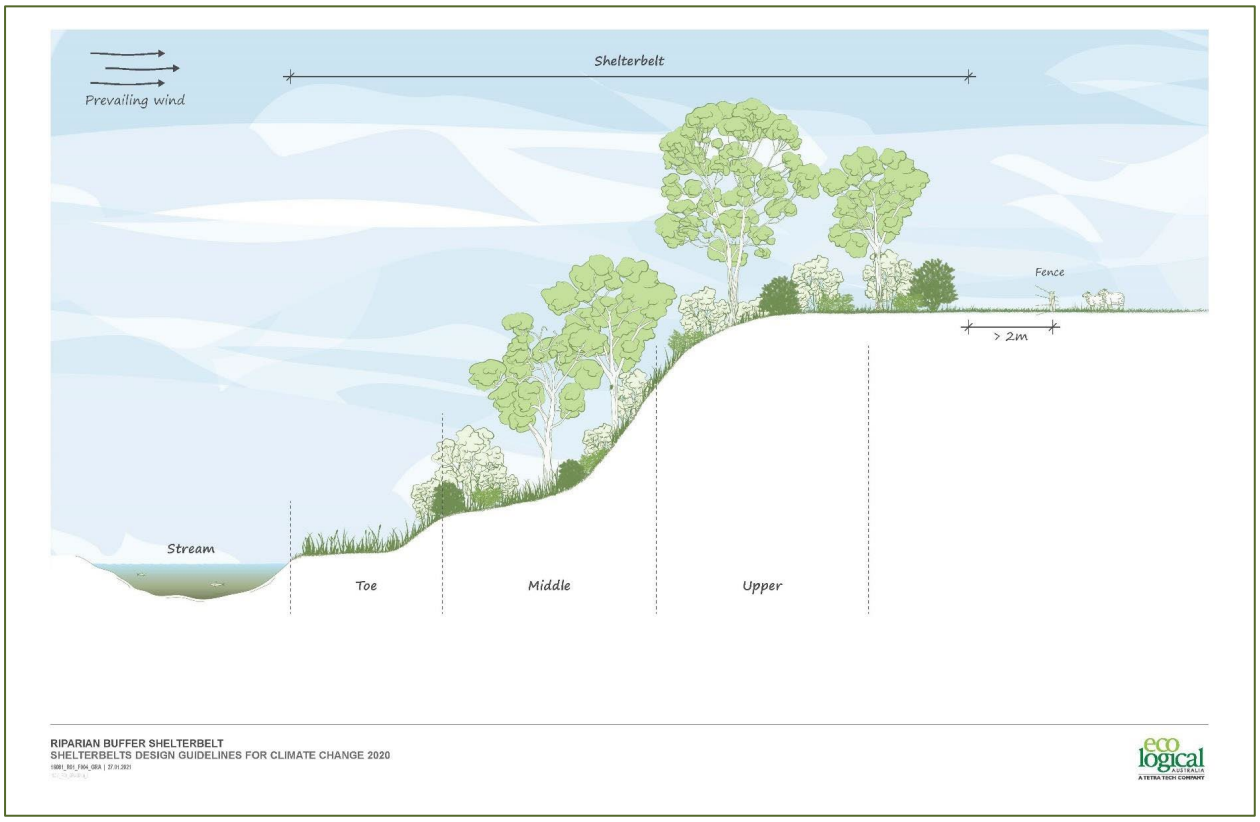
- the areas within the Victorian Government's *Metropolitan Bushfire Management Strategy* (MBMS) defined as 'extreme' or 'very high'
- land within residential and neighbourhood zones
- lot sizes less than 2000m^2 that cannot meet the vegetation setback distances described in Appendix F1.

An additional 150m buffer was applied from the excluded township boundary area. Refer to the detailed connectivity mapping in Appendix H and Figure 8 for the defined excluded township areas. Link to the Biolink interactive map. Biolink corridors around townships within the bushfire management overlay need to be responsive to future changing bushfire assessments associated with township reviews.

Opportunities for landscape connectivity within townships are generally limited to those species with moderate to higher mobility, tolerant to urbanised landscapes and vegetation structure that is clumped and spatially separate. Notwithstanding this, a range of rare and threatened species are still found in rural townships (refer Section 7.5.3) and will also benefit from township conservation actions. Opportunities exist for residents to work together to develop habitat connectivity at a residential property level to enable mobile and adaptable species to move through the landscape on the provision this does not elevate fire risk. Planting specifications at a property scale that utilise CFA design guidelines are identified in Appendix F1.

While terrestrial biolink corridors have been excluded from township areas, 'conservation corridors' have been identified along waterways within Emerald, Cockatoo, Upper Beaconsfield, Gembrook and Maryknoll townships. These corridors are described in more detail in Section 8.3. The goals within all conservation corridors are to enhance the quality of habitat through a set of limited conservation activities that do not increase the extent the corridor. Therefore, no large-scale revegetation works are proposed within conservation corridors. Figure 12 identifies the typical extent of retained vegetation along a waterway within a conservation corridor and depicts that the vegetation extent will not increase into the terrestrial area of any township.

Figure 12. Cross-section of retained vegetation along a waterway



Priority and future biolink corridors are identified along riparian waterways within Cardinia Creek, Gum Scrub Creek and Toomuc Creek which provide significant connectivity for species moving north and south through the shire. Conservation works include the suite of seven conservation opportunities including revegetation to connect large areas of cleared waterway with existing remnant vegetation. Works are focused on the riparian corridor and are not proposed to extend into the terrestrial area. The decision support matrix (refer Section 10.4) provides the direction to collaborate with the MFMPC for revegetation projects greater than 1000 trees and shrubs to ensure bushfire risk is considered for landscape scale projects.

In central and southern townships with reference to Bunyip, Garfield, Tynong, Cora Lyn, Bayles and Koo Wee Rup, specific habitat opportunities exist for the endangered Southern brown bandicoot (*Isoodon obesulus)*. Future corridors are located on the outskirts of the township primarily along utility corridors. Opportunities exist within the townships to provide connectivity through stepping-stone habitat to enable species to move through townships. While the priority for vegetation management in the township is to manage bushfire risk through planting which is isolated and spatially separate and setback from assets, habitat can still be provided by planting a mosaic of shrubby vegetation. Habitat should have a dense understory and open patches for foraging, within or adjacent to cover. The understorey should form the dominant component of the habitat; more understorey species planted than medium-sized shrubs, and only a few trees planted. The understorey should provide at least 50% average foliage cover in the 0.2–1m height range (Bernadette, 2016). Opportunities exist to create bandicoot habitat within road reserves, vegetated swale drains and on private property. Artificial habitat structures could play an important role to provide habitat which enables spatial separation of vegetation fuel loads. Council's gardens for wildlife program can plan an important role to advocate for the creation of SBB habitat.

9.3.4 Shelterbelts

Cardinia Shire supports the use of farm shelter belts because of the multiple positive outcomes that they can provide to rural properties and biodiversity. Shelterbelts can provide or enhance important biolink corridors within the landscape across private land where corridors would otherwise be sparse or absent. Shelterbelts can provide multiple benefits for farms beyond providing shelter from wind, including:

- increased farm productivity (including improvements in crop yields (12.5%), pasture yields (20-30%) (Bird, et al., 1992), dairy milk production (10-20%) and reductions in newborn stock deaths (8%) (Bird, Lynch, & Obst, Effect of shelter on plant and animal production, 1984; Bird, Lynch, & Obst, Effect of shelter on plant and animal production, 1984)
- improved ecosystem services such as higher pollination of crops, protect soil, cycle nutrients, moisture retention, erosion management and aesthetic landscape values
- asset protection in relation to natural disaster and weather events
- improved water quality outcomes
- native species can also assist in improving pasture health and the control of pests that impact crops.

Managing the structure of the vegetation can influence fire behaviour by considering the following planting elements:

- density and width
- height
- number and types of rows of plants
- orientation/layout
- spacing between shelterbelts
- shelterbelt design continuity and uniformity
- species selection.

The following specifications for shelterbelt design have been adapted from 'effective shelterbelt design' (Agriculture Victoria 2020) and the functional connectivity improvements set out in Appendix E.

Table 20. Shelterbelt design specifications

Shelterbelt design element	Specifications	Outcome
Trees	• Use of tall indigenous eucalypt species. • Where not practical/possible, utilise native eucalypt species.	• Enhances structural connectivity for birds, bats, and mammals that spend the majority of their time in trees (arboreal mammals.) • Tall species increase the effective windbreak area.
Shrubs	• Use of indigenous shrub species in between or in front of tree plantings. • Incorporate nectar-producing native species, *Acacia, Callistemon, Grevillea* and *Banksia*.	• Increases effectiveness of shelterbelt as a windbreak. • Dense native understory will provide structural connectivity for shrub-dependent species. • Provide food for nectar-feeding birds and attract native bees.
Groundcover	• Where permanently excluding stock from shelterbelt, add native ground-layer species such as *Lomandra longifolia.*	• Including groundcover increases effectiveness of shelterbelt as a windbreak.

Shelterbelt design element	Specifications	Outcome
	• Alternatively, fodder species may be utilised where stock access is required	• Groundcover provides an important resource for animals for foraging, nesting, resting, perching, basking or escaping from predators.
Existing vegetation	• Where possible, design shelterbelt to incorporate existing patches of native vegetation or scattered trees.	• Cost-effective. • Retains local biodiversity which is already present. • Connects island patches or scattered trees to other vegetated area.
Density	• Aim for medium density cover 40-60% • Plant a variety of tree, shrub and groundcover species to create an even density vertically. • Avoid gaps, stagger rows of trees and shrubs or utilise 'island shelter' in front of gaps for gates.	• Reduced wind turbulence • Extends the down-wind protected area • Increase effectiveness of shelterbelt as a windbreak • Maintain connectivity for animal movement • Increases biodiversity through use of various plant types.
Width	• Aim for at least 10 metres to facilitate connectivity for common species, or 50 metres for sensitive species	• Maintain connectivity for wide range of fauna groups • Increases biodiversity through provision of core habitat.
Weed and animal control	• Undertake weed removal prior to planting or sowing. • Use stock-proof fencing to protect new shelterbelts prior to planting • Use tree guards, or similar, to allow plants to establish.	• Reduced competition for establishing plants • Long-term positive outcomes for biodiversity through reduction in weed species • Increased success rate of plantings

By incorporating fire planning principles in shelterbelt design (refer to Appendix F1), features such as fuel management zones that are designed within the planted area can enable landholders to manage fire risk within a planted corridor. Further details on fire planning principles for vegetation are provided below.

Shelter belt project

In consideration of a changing climate Council and the Western Port Catchment Landcare Network are currently researching a shelterbelt design research project. The research will inform guidelines for shelterbelts to consider multiple values including:

- farm productivity and land classes
- ecological goals (threatened ecological communities and species, biolinks)
- ecosystem services (e.g. pollination, moisture retention, erosion management, wind reduction, biosecurity, shade and shelter)
- asset protection in relation to natural disaster
- landscape values
- improved water quality outcomes.

The guidelines will identify:

1. summary of the benefits of each value to achieve multiple objectives across the broader property
2. provide examples of plant characteristics to guide plant selection
3. provide cross sectional diagrams as examples for different shelterbelt layouts incorporating different landscape types, bioregions and property zones
4. provide an example of a property scale shelterbelt layout.

Carefully designed voluntary shelterbelts can provide habitat opportunities for the Southern brown bandicoot in rural areas within the special use zone. This plan advocates that 10-metre-wide native shelter belts will meet the sustainable farming practises purpose of this zone while also providing a suitable habitat outcome for species.

9.3.5 Constructed drains and channels

Constructed drains and channels are a significant feature within the southern region and where vegetated they can provide an important linkage between small, isolated remnants. Many of these linkages are short lived (ephemeral), with slashing for maintenance and management access substantially reducing biomass for a period, before the vegetation may become overgrown again. Increasing the permanency of connections along drains and channels may enhance the dispersal of populations and provide gene flow across the landscape (e.g. DEPI 2014), though it is unlikely this vegetation itself would support long-term populations.

Residents within the Melbourne Water drainage scheme pay a levy for Melbourne Water to slash these drainage lines to meet their primary drainage purpose. Southern brown bandicoots are likely to utilise the remaining unmown connected habitat which is often located along the water's edge. While revegetation is contrary to the drainage function of this asset, in the context of these priority locations, there is value to collaborate with Melbourne Water on the opportunities to provide for wider unmown widths of grass along the water's edge to bolster these priority habitat corridors.

The *Southern Brown Bandicoot Strategic Management Plan* (Ecology Australia 2009) identifies rehabilitation of vegetation along watercourses within the former Koo Wee Rup swamp area as a key management action, which will significantly contribute to the maintenance and enhancement of the southern brown bandicoot population. The development of biolink corridors along these watercourses supports this action. Additional recommendations for vegetation management along drainage lines include:

- consideration to providing corridor functionality on private land adjacent to public drainage corridors
- modifying slashing and grazing along key drainage lines located within biolink corridors

- while still enabling drainage functionality, infill planting on public and private land along drainage corridors with dense vegetation along most of their length (e.g. swamp scrub) to increase permanency of vegetation and formalise the corridors, and improve the continuity, quality and density of the understorey vegetation
- targeted revegetation of important drainage corridors which could provide linkages between patches of habitat
- staged weed control - removal of dense weeds (such as blackberry) to be planned with pre- and post-weed removal planting of native vegetation to maintain adequate coverage of vegetation for habitat
- utilisation of shelter belts on private property in lieu of wide corridors, especially in 'special use' zoned land which is designated for its agricultural productivity.

9.3.6 Natural waterways

Natural waterways and the adjoining land-based (terrestrial) habitat in the north of the shire, provides important connectivity for fauna within urban and peri-urban areas due to barriers associated with roads, housing, infrastructure and intensive land use practices.

By implementing sound conservation management to protect and enhance waterway corridors, riparian areas will be more resilient to environmental impacts including those exacerbated by climate change such as:

- increased bank stability
- a decrease in weed infestations
- provide native vegetation, biodiversity and habitat
- improved water quality, turbidity and nutrient levels
- contributions to the food web for in stream biota
- increased shading of streams, therefore keeping water temperatures within their natural range.

A key focus for conservation efforts should be maintaining and restoring riparian vegetation along these corridors to improve connectivity. Collaborative opportunities exist with Melbourne Water while working within the 'CFA Riparian land and bushfire' (DELWP, 2017) guiding principles. In this way Melbourne Water organisational 'vegetation priority areas' can be safely targeted to mapped biolink areas. Appendix K and L identify bushfire risk measures and the safe setback distances for riparian plantings. Aligning work priorities could identify synergies in resources for both Council and Melbourne Water in the form of:

- capital works projects
- synergies with growling grass frog habitat within the Melbourne strategic assessment area
- pest animal initiatives
- novel opportunities to realise the creation of new habitat by modifying historic maintenance practises i.e., management of drainage corridors.

The required width of riparian corridors (setback width) varies between fauna species and is also influenced by additional landscape and environmental factors including:

- land use intensity
- habitats present within the setback
- physiography, including slope, geology and position in the catchment
- hydrological features, including wetlands, floodplains and swamps
- infrastructure within the setback.

These issues should be considered for each site prior to the implementation of any revegetation works. Ecology Australia has undertaken a detailed review of minimum setback widths for Melbourne Water in 2009 and 2018, the findings from these studies are outlined in Table 19 and Table 20. This provides general minimum setback widths based on the ecosystem function or management

objective and detailed setback widths for groups of fauna. Based on a species sensitivity to riparian vegetation width (setback width) as low, moderate or high sensitivity.

Table 21. Recommended minimum setback widths for streams in Port Philip and Western Port regions

Ecosystem function/management objectives	Recommended setback width*
Terrestrial biodiversity: terrestrial fauna	100m + (range 30–290m)
Terrestrial biodiversity: riparian-dependent fauna	50m + (range 30–500m)
Terrestrial biodiversity: flora	55m (range 20–500m) + Tree Protection Zone of trees rooted or partially rooted within the setback
Instream values	30m (range 5–106m)
Water quality	30m (range 1–190m)

*These setback widths should be measured from the 'edge of the bank' as described in the Waterway Corridors guidelines (Melbourne Water 2013).

Table 22. Detailed minimum riparian setback widths for fauna groups (Ecology Australian 2009) with key habitat elements

Minimum setback width	Key habitat elements	Example fauna
20m (low sensitivity species)	• Low diversity of flora and vegetation structure (primarily grasses and reeds) • In-stream aquatic vegetation and basic fringing vegetation • Provides minimum food resources and habitat elements (some snags, rocks, debris and leaf litter) • Unshaded open areas for basking (frogs)	Birds – Eurasian coot, dusky moorhen, purple swamphen and Australian wood duck Frogs – southern brown tree frog, pobblebonk and striped marsh frog Mammals – rakali Fish – short-finned eel, short-headed lamprey and common galaxias
40m (moderate sensitivity species)	• Slightly more diverse flora and vegetation structure (grasses, reeds and some trees or shrubs) • Mix of tall/low shrub cover • In-stream aquatic and fringing vegetation • Slightly more food resources and habitat elements (some large logs and rocks, debris, moderate leaf litter depth) • Wet depressions (Victorian smooth froglet) • Unshaded open areas for basking (frogs)	Birds – Australasian grebe, Australasian bittern, Baillon's crake, buff-banded rail, chestnut teal, white-necked heron, black-fronted dotterel, little black cormorant, little pied cormorant, black swan, Latham's snipe, eastern great egret and little egret Frogs – Verreaux's tree frog and Victorian smooth froglet Invertebrates – Gippsland giant earthworm Reptiles – eastern long-necked turtle and red-bellied black snake
50m+ (high sensitivity species)	• Complex native vegetation structure and flora diversity (ground layer, mid-story and canopy) • Reduced canopy cover gaps < 30 m	Birds – Powerful owl, Swamp harrier, Azure kingfisher, White-faced heron, Royal spoonbill, Nankeen night heron

Minimum setback width	Key habitat elements	Example fauna
	• Dense understory with multiple native species • Mix of tall/low shrub cover • Tree hollows for hollow-dependent fauna • Good water quality • More diverse In-stream aquatic and fringing vegetation • Submerged logs and branches • In-stream detritus and rock • High cover of different sized logs, rocks and leaf litter • Stable river and creek beds • Open areas for basking or foraging • Wet depressions (Southern toadlet) • Management of wetland hydrology to control predatory mosquito fish (*Gambusia affinis*)	Mammals – Southern brown bandicoot, Yellow-bellied glider and Platypus Reptiles – Swamp skink Frogs – Southern toadlet and Growling grass frog Invertebrates – Southern Victorian spiny cray Fish – Dwarf galaxias and Southern pygmy perch.

Some high sensitivity species require greater setback widths and where detailed setback information exists these guidelines should be implemented. These include:

- growling grass frog - 200m (Ecology Australia 2009)
- powerful owl - 250m (DSE 2004; Ecology Australia 2009))
- southern Victorian spiny cray - 100m (Ecology Australia 2009)
- swamp skink - 100m (Ecology Australia 2009)
- yellow-bellied glider - 200–250m (Kavangh and Rohan-Jones 1982; Recher et al. 1987; Ecology Australia 2009).

Where landscape and environmental factors affect a site, increased minimum setback widths are recommended to achieve ecosystem function. These include:

- intensity of land use e.g. agricultural vs urbanisation
- required by threatened species
- steep catchments
- poor soils (e.g. impermeable soils)
- headwaters
- wetlands and floodplains should be assessed based on the specific values on a site-by-site basis
- where paths are within 30m of a waterway, increase setback by width of the disturbance zone (e.g. 5–10m for a 3m shared path). Avoid paths within the riparian zone where possible.

9.3.7 Utility easements

Areas of public land which are reserved for a utility (e.g. drainage lines, powerline, gas easement, roads and rail reserves) are set aside with the primary purpose to provide that utility function. As development increases, utility assets will logically intensify in their extent within the easement. Where native vegetation exists along a utility easement or could be planted to provide a vegetation corridor presents a competing and potentially conflicting use. Utility easements can provide conservation outcomes where this does not conflict with the primary purpose of the utility. An example of this is where low shrubby understory is planted beneath the transmission lines for ground dwelling mammals or where habitat is managed on the outer edge of the utility easement.

The plan identifies a goal to create shared responsibility for conservation management outcomes on private and public land. A progressive transition that provides native vegetation corridors on private

land away from public utility zones over the long term will build resilience into the biolink which will insure corridors against future potential utility asset upgrades. This will require Council and conservation partners to work with private landholders to plan the transition of strategically important biolink corridors which are sustainable into the future.

Notwithstanding these constraints, opportunities exist to realise connected corridors in utility easements can be achieved through careful planning and working within utility easement guidelines such as the SP Ausnet planting guidelines (AusNet Services) and GasNet Australia (APA) landscape guidelines (APA, 2019). APA gas easements enable conditional small shrubs and ground covers to be planted anywhere within the easement, while medium to large shrubs and small trees can only be planted along the outer three metre edge of the easement (away from the three metre pipe buffer zone).

9.3.8 Road and rail reserves

Road and rail reserves play a role in providing connectivity due to the persistence of remnant or recolonising vegetation in otherwise cleared landscapes. While narrow, these corridors often support a diversity of structure and include rare and significant species some of which cannot practically be propagated through commercial nurseries. Roadsides were generally not identified in the connectivity assessment as providing core habitat for species or acting as priority biolink corridors, they are considered valuable for the role they play in providing functional connectivity to link more important habitats in the landscape.

A VicRoads tree policy exists to manage environmental outcomes on VicRoads land within the policy principles of road user safety, road network efficiency, sustainable transport, cost efficiency, sustainability and community wellbeing (VicRoads, 2016). Revegetation and habitat improvements require a safety assessment. The safety risk to road users to meet setback standards of vegetation from the roadway can be addressed by installing approved safety treatments (e.g. wire rope barriers or guardrail) or through other innovative solutions documented and approved using a principle-based approach. Novel solutions such as construction of artificial habitat also exist.

VicTrack land is set aside for transport purposes. V/Line and Metro Trains Melbourne lease most of the northern Pakenham/Warrigal corridor. The unused South Gippsland corridor is leased through a variety of mainly private leases. Environmental management is an important part of VicTrack's operations, as one of their main non-commercial activities, and as the asset owner of one of Victoria's largest titled land holdings. VicTrack regularly completes biodiversity assessments across the state to understand significant flora and fauna values on VicTrack land and put in place measures for ongoing management.

The presence of habitat on road and rail reserves can also pose risks to fauna due to injury and mortality associated with transport activities, as well as the changes in foraging, reproduction and social behaviours associated with increased noise and movement. The management of roadsides also cater to an exceptionally wide variety of uses ranging from the need to provide safe vehicle passage, location for utilities, drainage and recreational functions. While the Biolink Plan advocates to retain existing roadside and rail vegetation to provide connectivity for biodiversity, a progressive transition to provide vegetated corridors on adjacent private land is viewed as a longer term preferable sustainable environmental outcome. Over the long term this will avoid the conflicts with competing land uses within this narrow vegetation corridor. Such a transition is not a straightforward process, as it is not practically possible to completely replicated the floristic (number, type and distribution of flora) diversity of roadside vegetation within cleared landscapes on private land through revegetation.

The landscape connectivity mapping (refer to Appendix H) provides an emphasis on linking core areas of habitat rather than the movement of species along the length of the roadside. Where multiple competing land management uses apply to a roadside, as a minimum the Biolink Plan

advocates to work within the gap crossing thresholds for low, moderate and high mobility species to facilitate lateral movement of species across roadsides.

Council has phased the development of a Roadside Management Plan in 2022-23 (as set out in the *Biodiversity Conservation Strategy 2019*) to strategically manage these multiple roadside uses and achieve multiple land management outcomes as best practise within this space. Council has standard clearance setbacks and a roadside slashing regime to ensure safe trafficability of roadways. Council also works with the CFA through the Municipal Fire Management Planning Committee (MFMPC) to manage roadsides designated strategic and tactical access roads. No new biolink corridors are identified in the Biolink Plan that have been positioned along the length of any strategic or tactical access roads. These roadsides offer optimal locations to manage fire behaviour at a landscape scale by designing strategic fire breaks at designated roadside locations.

A research project supported in the action plan is currently being undertaken by Council to investigate the fire response along roadsides to a variety of different fuel loads. The multi-year project will make comparative assessment of fire response along roadsides with different species, altered vegetation structure (i.e. absence of shrub storey) and spatially separated vegetation. The outcomes can inform Council's future roadside management practises.

A desktop assessment of the shire's unconstructed government roads was undertaken as part of the Biolink Plan and is included in Appendix G. Unconstructed government roads are historic road reserves that have never formally been cleared and defined as a roadway. They can contain high quality remnant native vegetation and can have significance in providing biolink connectivity to surrounding landscapes. The desktop audit found 318 separately assessed 'reaches' of road over a total length of 309 kilometres. Metrics that were assessed included collecting geolocation references, the percentage of vegetation cover, length and environmental connectivity assessment that the road provides in the broader landscape. A key action of this plan is to work with DELWP to determine the delegated licenced land manager for any unconstructed government road reserves.

Utilising this data, Council will then develop a database of unconstructed government roads, including:

- title information
- land status of each road that have been formally closed
- licencing information
- ownership (if Council or DELWP).

The information in this database will be used to inform the appropriate management of these assets. The environmental assessment data will enable Council to advocate for conservation management outcomes for the highest conservation significance unconstructed government road reserves.

Table 23 outlines the design opportunities that can be considered to facilitate fauna connectivity along road and rail corridors and adjacent land.

Table 23. Mitigation measures and recommendations for road and rail reserves

Asset	Action
Road reserves	• Collaborate with the Municipal Fire Management Planning Committee on large scale biolink treatments across roadsides. Avoid strategic and tactical access roads • Corridors should be at least 100m wide where possible to reduce the impact of edge effects • At the conception and planning stage consider the impact of road extensions or upgrades to remnant vegetation, connectivity and fauna hotpots and plan to avoid or reduce or impacts and habitat fragmentation where possible

Asset	Action
	• Consider the opportunities to provide corridor functionality along adjacent private land • Implement wildlife crossing structures to facilitate fauna egress such as underpasses, culverts and canopy bridges in fauna hotspots to reduce vehicle induced mortality considering: – use funnel fences to divert fauna into crossing structures – build culverts with a ledge to increase fauna use when water is present in the culvert – animal visual and audible deterrent devices – place rocks and logs at the entrance of culverts and ensure protective cover such as trees or shrubs are also provided – install animal crossing awareness signage for motorists • Install frog-resistant fences in high-volume crossing areas • Ensure that fences are designed to keep wildlife out such as above, are suitably designed, e.g. floppy top, chain mesh and pinned down skirting to discourage climbing animals and kangaroos. Frog-resistance fences need to be dug down to a depth of at least 100mm – leave a 30-50cm gap between the bottom wire and the ground to enable fauna to pass underneath – do not use barbed wire; instead, use plain wire – ensure that the fence is visible to fauna by attaching reflective/colourful tags at 30 cm intervals and use borderline (white plastic coated) wire or white tape for the top strand. – post and rail fencing is the most wildlife-friendly – avoid erecting fences on ridgelines, near fruiting or flowering trees, across wildlife corridors, or over dams or waterways. • Where possible increase the canopy cover and shrub cover along road reserves and median strips to increase safe passage of fauna across roads • Plant native species that are represented within the relevant EVC • Create native wildlife corridors in road reserves to improve connectivity between patches of remnant vegetation. • Plant shrubs closer together to aid in dispersal of small birds and bats that move only short distances between shrubs • Retain hollow-bearing trees. Where tree hollows are limited, consider installing artificial hollows e.g. chainsaw hollows or transplanted hollow-bearing trees or tree sections. • Greater opportunity exists to utilise roadside vegetation for habitat in the southern region due to the lower bushfire risk while still being considerate of drainage requirements.
Rail reserves	• Corridors on unused rail reserves should be at least 100m wide where possible to reduce the impact of edge effects although on currently used transport routes a narrow corridor on the outer edge of the reserve is more practically feasible • Plant shrubs closer together to aid in dispersal of small birds and bats that move only short distances between shrubs. Smaller shrubs less than 3m tall are less likely to interfere with rail operations • Consider the opportunities to provide corridor functionality along adjacent private land • Retain hollow-bearing trees. Where tree hollows are limited, consider installing artificial hollows e.g. chainsaw hollows or transplanted hollow-bearing trees or tree sections. • Keep new plantings on the outer edge of the easement, a safe distance from the track edge. It is critical to use the vertical height of the vegetation as a measure of the distance to keep away from the track.

Asset	Action
	• Ensure that driver vision is not obscured by planting. Observe clear zones particularly near level crossings, track signals and signal boxes • Where practicable, establish native vegetation on batters and embankments to prevent erosion • Plant native species that are represented within the relevant EVC with an aim to create complex vegetation structure (canopy, mid-story and ground layer) that are diverse floristically • Minimise weed invasion to reduce bushfire risk.

Ecological burning

Fire is part of the natural Australian ecology that stimulates native species lifecycles and creates habitat for native fauna (Kenny, 2004). The creation of many multi-aged landscapes that are within the tolerable fire intervals for an Ecological vegetation division (EVD) is considered the preferential burning regime because this creates a mosaic patchwork of different aged landscapes which will provide the optimal habitats for the most diverse number of species (Cheal, 2010) (Fox 1986) (Gill M, 1986) (Fox, 1996). The consequences of burning outside of ecological parameters results in species loss because frequent fires alter the plant species composition and vegetation structure of their habitats (Cheal, 2010) (Gill A. M., 1999) (Tran C., 2000) (Tran C., 2000).

Council's Municipal Fire Management Plan guides the management of fire and other fuel hazards within Council's public reserve system to promote the health and wellbeing of our natural, social, built economic and cultural environments. Where burning occurs within the tolerable fire intervals of the EVD this can have beneficial consequences for biodiversity. However, the primary goal of Council's fuel reduction program is for the protection of life and property. This different goal typically compels for more frequent burning regimes than the natural vegetation tolerable fire interval would direct because areas of recently burnt vegetation provides an opportunity for fire authorities to supress a fire (Gould, 2007).

A future strategic bushfire management plan will define priority areas for fuel reduction and will be implemented through the Municipal Fire Prevention Planning Committee. Council's fuel reduction program and fire management planning will complement the strategic bushfire management plan in that they share the goal to define and protect asset protection zones which are usually associated in proximity to townships. This plan has identified biolink corridors away from bushland reserves in these asset protection areas to avoid this conflict. Where an asset protection area is identified within a biolink corridor, opportunities exist to divide the reserve up into different management zones to find multiple land management outcomes within the same locality. This could include more frequently burning a defined asset protection area considerate of the range of tolerable fire intervals within the EVD to meet fuel hazard objectives while avoiding sensitive riparian areas further away from the asset. Biomass treatments other than burning in asset protection zones can also be considered.

Ecological burning opportunities that could be explored which could also have fuel reduction benefits include the use of Traditional Owner 'cultural fire practises.' This involves burning vegetation in a different way to European style 'cool burns,' utilising cultural fire knowledge and practise. This practise reportedly can be undertaken for a wider period within the year compared to post settlement fuel management practises. Partnership meetings with the Traditional Owners will further investigate this opportunity and are identified in the action plan.

Ecological burning opportunities should also be explored on private land to create multi aged vegetation classes that are within vegetation tolerable fire intervals. Currently there are issues and constraints relating to successful burning on private land. These include:

- varying degree of resident knowledge to manage their burn from a logistic and operational perspective
- goal setting to meet ecological needs to maximise biodiversity
- limitations for smaller land parcels
- risk management of the fire burning outside specified planned area
- appropriate resources to safely carry out the burn
- lack of procedural methodology for post burn management including weed control and restricting stock from accessing the burn site
- conforming to planning controls in post burn landscapes
- cost constraints to prepare, implement and manage the post burn works
- need to holistically coordinate burning on private land to meet ecological needs and achieve a multi-aged mosaic of vegetation landscapes.

The action plan identifies the need to work with the Emergency Management department to investigate a framework to facilitate ecological and fuel reduction burning on private land.

The development of the *Victorian Traditional Owner Cultural Fire Strategy* was created to support Traditional Owner rights and interests in reintroducing cultural fire to the landscape. The strategy defines Aboriginal [cultural] fire as caring for Country. Cultural burns are used for cultural purposes and that they are not simply about asset protection. Cultural burns protect sites and clear access through Country for cultural uses including hunting, access to fish traps and ceremony.

The strategy defines principles for cultural burning including:

- cultural burning is right fire, right time, right way and for the right (cultural) reasons
- burning is a cultural responsibility
- cultural fire is living knowledge
- monitoring, evaluation and research to support cultural objectives and enable adaptive learning
- country is managed holistically
- cultural fire is healing.

The strategy outlines four objectives and corresponding program components with possible action that will enable Traditional Owners to lead the practise of cultural burning occurring to the strategy principles.

The Firesticks Alliance Indigenous Corporation also provides Indigenous leadership, advocacy and action to protect, conserve and enhance cultural and natural values of people and Country through cultural fire and land management practices. The Firesticks Alliance provides an informative role to the *Victorian Traditional Owner Cultural Fire Strategy*. The action plan identifies an action to explore the use of traditional owner cultural fire practise burning.

Extract industry treatments

Twenty-six current extractive industry tenements are identified within Cardinia Shire. A further 28 extractive industry interest areas are located throughout the shire. The location of the current tenements are identified on the landscape connectivity maps. Any planned biolink conservation works must be considerate of the development potential within these areas prior to commencing works. In Victoria where a mining development proposal will have a 'significant environmental impact' and meets referral criteria set out in the ministerial guidelines for assessment of environmental effects, a referral would be required under the *Environment Effects Act 1978.*

The process under this act is not an approval process itself, but rather enables statutory decision-makers (ministers, local government and statutory authorities) to make decisions about whether a project with potentially significant environmental effects should proceed. If the Minister for Planning

decides that an Environment Effects Statement (EES) is required, the project proponent is responsible for preparing the EES.

Dependant on the outcome of the EES, multiple land management outcomes could be achieved including biolink connectivity even if the proposed extraction proceeds. This could include the creation of habitat corridors on the outer perimeter of the extraction site. Such habitat should be tailored to the target species that is to be conserved.

10 Planning and implementation

Effective planning and implementation of management priorities is critical to achieving biodiversity conservation outcomes, particularly where efforts are being undertaken at a landscape-scale and conservation assets are located on private land.

To inform this process, this section presents:

- the results of the prioritisation analysis
- biolink planning and context in the Victorian planning provisions
- aboriginal heritage act
- decision support matrix for safe biolink
- implementation
- monitoring and review.

10.1 Biolink planning and context in the Victorian planning provisions

As the responsible authority for planning decisions across the shire, Council has a critical role in protecting and conserving biodiversity through the Victorian Planning Provisions (VPP) under the *Planning and Environment Act 1987* and other legislation, regulations and policies.

The Victorian Planning Provisions guide the appropriate outcomes for the use and development of land. Planning assists to achieve multiple land management outcomes across the landscape. This plan identifies operational actions to create and enhance strategic habitat corridors throughout the shire. The plan has not been developed for inclusion into the planning scheme but after future corridor risk analysis may act as a resource for the creation of planning scheme content. Notwithstanding this, the actions that are identified in the action plan will utilise statutory land management directions as best practise to guide the voluntary implementation of this plan. An example of this is the use of setback standards from buildings and dwellings in clause 44.06 and 52.12 to inform biolink design. Clause 13.02 ‘provides the direction to strengthen the resilience of settlements and communities to bushfire through risk-based planning that prioritises the protection of human life.’ This fundamentally guides many aspects of the plan implementation such as the collaboration with the Municipal Fire Management Planning Committee who will review the bushfire hazard for new biolink proposals.

This plan informs the establishment of wildlife and habitat corridors, connected corridors, biolinks, buffer zones for waterways or sustainable farming practises including shelterbelts which are referenced in 21 separate planning clauses. Clauses 12.01, 13.02 and 14.01-1 of the Victorian Government planning policy framework provide significant direction in the Biolink Plan on the strategic establishment of native vegetation corridors and the safe implementation of biolinks which has guided the development of this plan. These are summarised below with other clauses relevant to this plan listed in Appendix I

10.1.1 Summary of clause 12.01s protection of biodiversity

Objective

To assist the protection and conservation of Victoria's biodiversity

Strategies

- Use biodiversity information to identify important areas of biodiversity, including key habitat for rare or threatened species and communities, and strategically valuable biodiversity sites.
- Strategically plan for the protection and conservation of Victoria's important areas of biodiversity.
- Ensure that decision making considers the impacts of land use and development on Victoria's biodiversity, including consideration of:
  - cumulative impacts
  - fragmentation of habitat
  - the spread of pest plants, animals and pathogens into natural ecosystems.
- Avoid impacts of land use and development on important areas of biodiversity.
- Consider impacts of any change in land use or development that may affect the biodiversity value of nationally and internationally significant sites; including wetlands and wetland wildlife habitat designated under the Convention on Wetlands of International Importance (the Ramsar Convention).
- Assist in the identification, protection and management of important areas of biodiversity.
- Assist in the establishment, protection and re-establishment of links between important areas of biodiversity, including through a network of green spaces and large-scale native vegetation corridor projects.

The plan responds to clause 12.01by:

- utilising a scientifically transparent methodology which identifies and maps the creation of a network of vegetation corridors that will provide functional and structural connected areas to sustainably support native species
- establishing a prioritisation analysis to identify locations supporting important habitat and linkages. This will inform strategic and operational planning decisions to ensure the highest value sites of biodiversity are protected and development does not impact important areas of biodiversity
- identifying the protection and enhancement of internationally significant Western Port Ramsar wetlands.

10.1.2 Summary of clause 13.02 bushfire planning

Clause 13.02 Provides the direction to strengthen the resilience of settlements and communities to bushfire through risk-based planning that prioritises the protection of human life. The provision is applied to land:

- within designated bushfire prone areas
- subject to a bushfire management overlay or
- land that is proposed to be used or developed in a way that may create a bushfire hazard.

This clause provides the consideration of bushfire hazard assessment on a landscape scale. Strategies which direct the implementation of clause 13.02 include:

- prioritising the protection of human life over all other policy considerations
- directing population growth and development to low risk locations and ensuring the availability of, and safe access to, areas where human life can be better protected from the effects of bushfire
- reducing the vulnerability of communities to bushfire through the consideration of bushfire risk in decision making at all stages of the planning process.

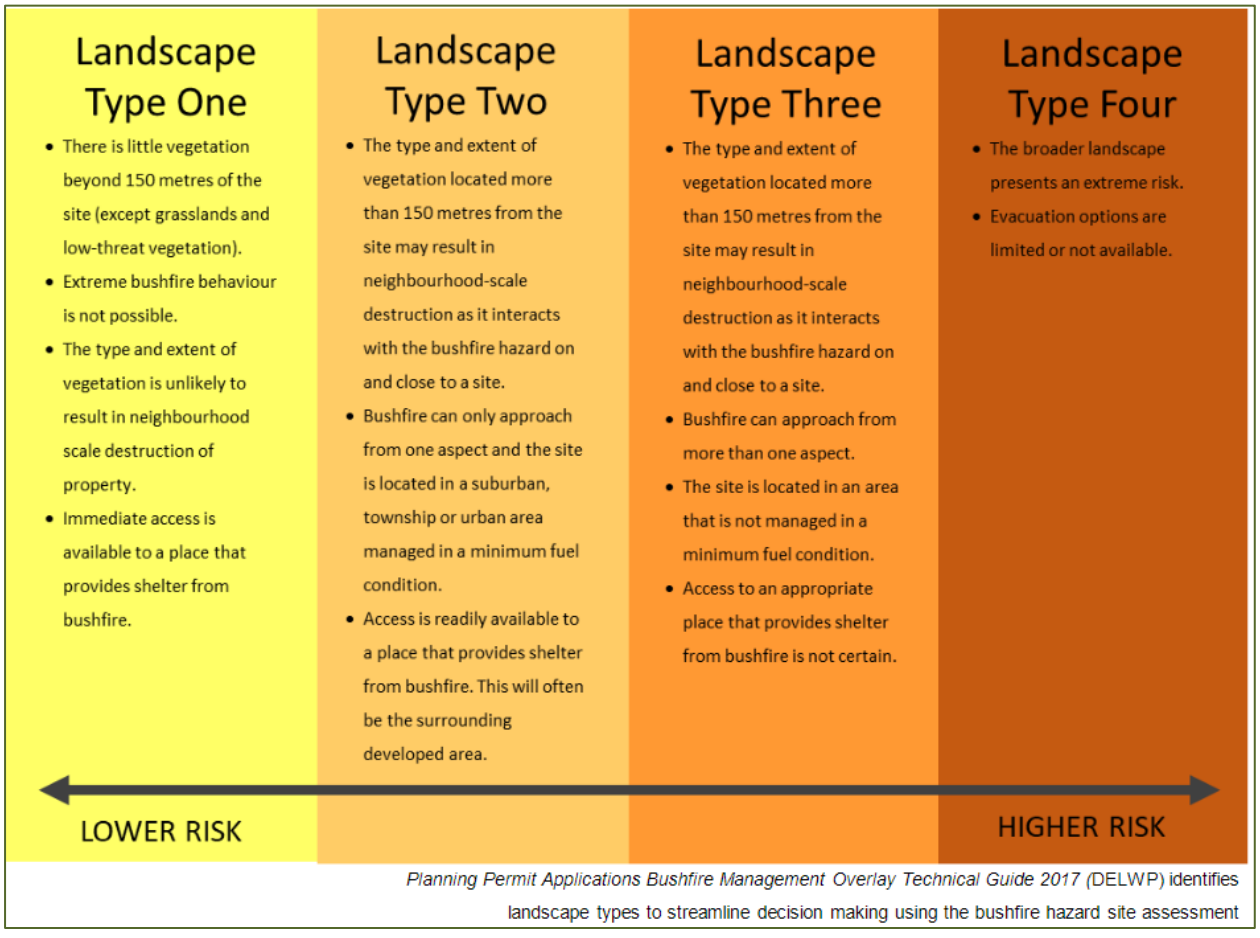
This clause also provides details on how bushfire hazard identification is made.

In addition to prioritising the protection of human life, this policy also requires that settlement growth and development approvals can implement bushfire protection measures without unacceptable biodiversity impacts by discouraging settlement growth and development in bushfire affected areas that are important areas of biodiversity.

The plan responds to clause 13.02 by:

- the planned liaison with the Municipal fire management planning committee who will inform vegetation management design features into landscape scale biolinks. The opportunities and limitations of fuel management works are detailed in Appendix F2.
- the incorporation of bushfire hazard assessment into conservation management decision making priorities the Biolink Plan utilises the DELWP landscape hazard assessment guide from the 'Bushfire management overlay technical guide,' DELWP, 2017. Figure 12 from the assessment guide describes landscape hazard into four hazard categories.

Figure 13. Guide to bushfire hazard landscape risk



Planning Permit Applications Bushfire Management Overlay Technical Guide 2017 (DELWP) identifies landscape types to streamline decision making using the bushfire hazard site assessment

The Biolink Plan generalises these hazard categories within the shire into two, 'higher' and 'lower' risk profile areas to reflect the:

- two homogenous vegetation types of the Koo Wee Rup lowlands and the shire's foothills and forests
- a conservative safety focus where community safety and asset protection are considered in all biolink action planning.

A decision support matrix has been developed to direct operational action planning in three different risk profile areas within the shire (refer to Section 10.4)

10.1.3 Summary of clause 14.02-1S water- catchment planning and management

Strategies

- Consider the impacts of catchment management on downstream water quality and freshwater, coastal and marine environments.
- Retain natural drainage corridors with vegetated buffer zones at least 30 metres wide along each side of a waterway to:
  - maintain the natural drainage function, stream habitat and wildlife corridors and landscape values
  - minimise erosion of stream banks and verges
  - reduce polluted surface runoff from adjacent land uses.
- Require appropriate measures to filter sediment and wastes from stormwater prior to its discharge into waterways, including the preservation of floodplain or other land for wetlands and retention basins.
- Ensure that development at or near waterways provide for the protection and enhancement of the environmental qualities of waterways and their instream uses.

The plan responds to clause 14.02-1S by:

- Identifying and mapping important areas of biodiversity which directly align with Cardinia Shire's creeks, streams and rivers including identifying setback standards for waterways to guide the creation of waterway buffers.

This plan meets action 'A10' of the Western Port Green Wedge Management plan to develop strategic corridors across this subject area and is supported by the Northern Ranges Green Wedge Management Plan issues paper which identifies the importance to identify and retain key habitat core patches and the corridors that link these patches.

10.1.4 Melbourne strategic assessment (MSA) program

The *Biodiversity Conservation Strategy for Melbourne's Growth Corridors* sets out the conservation measures required for Victoria under the Melbourne Strategic Assessment (MSA) Program to satisfy the commitments made to the Australian Government for species protected by the *Environmental Protection and Biodiversity Act*. In Cardinia Shire the growling grass frog is one of the listed species to be protected within the MSA program. The sub regional species strategy for the growling grass frog provides guidance on the important populations of growling grass frog and areas of habitat to be protected and prescriptions for habitat corridors. This will inform the design of precincts at the precinct structure phase and the preparation and implementation of a GGF Masterplan for Melbourne's Growth Corridors. These corridors are identified in the biolink interactive mapping.

The masterplan identifies areas of strategic importance within Cardinia Shire along a 6.3-kilometre reach within Cardinia Creek, south of Princes Freeway. Through careful design as part of the precinct structure planning process within Cardinia's growth corridors, areas of open space can complement GGF habitat needs which provides the opportunity to recolonise local waterways. The GGF also has the potential to become an iconic species in which to engage the community in their local natural environment. Melbourne Water regional retarding basins to the south will compliment habitat opportunities as they extend into the green wedge areas. The Cardinia Creek reach will be located within the Cardinia Parklands environmental – open space precinct which offers significant habitat dispersal opportunities and community engagement that is associated with a regional park.

10.2 Aboriginal Heritage Act

The regulations within the *Aboriginal Heritage Act* direct that 'high impact activities' in areas of 'cultural heritage sensitivity' require a cultural heritage management plan to be prepared to assess the likelihood of, and management of harm to any Aboriginal cultural heritage area. A 'high impact activity' includes any form of ground disturbance while 'areas of cultural heritage sensitivity' are defined on the Aboriginal Victoria (www.aboriginalvictoria.vic.gov.au) website. Within Cardinia Shire numerous natural waterways are identified as significant biolinks which are also typically defined as 'areas of cultural heritage sensitivity' within the act.

A process exists to gain approval from the Traditional Owners to undertake small scale activities such as fencing and tree planting in areas of cultural heritage sensitivity by entering into an Aboriginal Cultural Heritage Management Agreement (ACHMA). This agreement exempts specified small activities from submission of a Cultural Heritage Management Plan. A condition to meet the ACHMA criteria is that for each individual activity, a participant who has completed the cultural heritage training must be on site.

The action plan has identified the development of a collaborative process with the Wurundjeri, Bunurong and Boon Wurrung aboriginal parties to understand the opportunities and constraints of working within these areas to meet the requirements of the act.

10.3 Climate change

The plan will respond to climate risks to biodiversity in three priority themes which are outlined in Table 244.

Table 24. Priority themes for addressing risks to biodiversity from climate change

Priority theme	Rationale	How the plan responds to climate change
Improving our scientific understanding	Enhance understanding of the likely responses of biodiversity to climate change and readjusting management programs where necessary.	The identification of indicator species in the plan compliments Council's *Biodiversity Conservation Strategy* action to implement cyclic monitoring to understand the health of our indigenous flora and fauna. Utilising Council monitoring programs in partnership with community citizen science initiatives and university research will play an important role in contributing to the Council and communities' knowledge base to understand biodiversity responses to climate change.
Identifying strategic biodiversity priorities and corridors	Increase opportunities for species to move across the landscape by working with partners and the community to protect habitat and create the necessary connections within landscapes.	The biolink connectivity study will directly inform the understanding of existing and potential biolink corridors which support a diversity of flora and fauna species within the shire. Improving species connectivity increases species health and builds resilience to the effects of a changing climate.
Adaptation planning and management opportunities	Assessing adaptation options and supporting the resilience of climate-threatened ecosystems and species.	As part of adaptation planning climate vulnerable species will be identified to understand future conservation management implications. Future revegetation will need to consider the design principles identified in Appendix E with flexibility to adapt to alternative species which can provide habitat and also survive in a changing climate. This may include the use of native but non-indigenous species. Existing climate ready

		resources when revegetating for resilient biolink corridors will need to be considered including: • Climate-ready revegetation: A guide for natural resource managers (Hancock, 2016) • A Guide to Creating Climate Future Plots (Greening Australia) • Landcare Victoria, Climate Ready Revegetation (www.landcarevic.org.au). **The plan responds to the changing risk of bushfire by considering fire safety in biolink corridor objectives, design, planning and implementation.**

Investment opportunities that complement the protection and creation of biolink corridors that should be explored include:

- carbon sequestration through tree planting and 'carbon farming' by increasing pasture carbon content and farm composting
- blue carbon sequestration through proactive management to protect and enhance and mangrove, salt marshes and seagrasses
- utilisation of the 'Coastal adaptation pathways project' which is a collaborative initiative between the Municipal Association of Victoria (MAV), the Association of Bayside Municipalities (ABM) and the Central Coastal Board (CCB) can help to build a resilience framework for environment, private and public (community) assets.

Future proposed Council strategies and policies that will inform biolink adaptation planning and management include a Council climate change adaptation plan.

Complementary to this plan, Council is currently working with the Port Phillip and Western Port Catchment Management Authority and Landcare to develop a draft Shelterbelt Design Guideline document with a key goal to establish vegetated corridors that are resilient to climate change which are also safe to people and property. Shelterbelts that are designed to represent the local ecological vegetation community and are greater than 10-metres wide can provide functional connected biolinks for mobile species. This future document can inform future biolink corridor design.

10.4 Decision support matrix to implement safe biolinks

Cardinia Shire encompasses two different bioregions with different bushfire risk ratings and a variety of townships and settlements distributed throughout the landscape. To respond to revegetation and vegetation protection opportunities in these highly varied landscapes and land uses a decision support matrix has been created. The decision support matrix will achieve the plan's goals through consideration of:

- conservation objectives
- bushfire safety to people and property.

The Municipal Fire Management Planning Committee will assist in providing expertise on the conservation works that could present a bushfire risk to manage bushfire hazard. Actions such as artificial habitat creation and pest animal and plant removal and ecological burning are more likely to reduce fire behaviour and are therefore not considered for referral to the MFMPC.

The matrix provides guidance on how the plan will respond to small scale and large-scale revegetation and vegetation protection projects in risk areas defined in the Metropolitan Bushfire Management Strategy. The risk areas can be found in the plan mapping and comprise of an area within the Koo Wee Rup lowlands and two areas within the Cardinia Shire hills and forests. No structurally connected revegetation corridors (i.e., trees, shrubs and ground storey plants that are connected without gaps) are proposed within townships or the 150m bushfire site assessment area of any buildings (refer Section 9.3.1 and 9.3.2). Small scale initiatives are typically made up of

individual or a small number of properties over a single year which have negligible impact on bushfire risk at a landscape scale. Large scale projects typically occur over multiple years and involve many properties at a catchment scale which could have an impact on bushfire risk at a landscape scale.

Table 25, Table 26, and Table 27divide small scale and large-scale conservation works for each risk area.

Extreme – Very high landscape risk for house assets

No large-scale terrestrial revegetation or vegetation protection projects are proposed within the rural townships where an extreme or very high house asset risk area has been identified. Biolink corridors mapped in these areas are limited to 'conservation corridors' along waterways (refer Section 8.3). Within the urban growth boundary priority and future corridors are limited to the riparian waterway (refer Section 9.3.3). No large-scale revegetation projects are proposed within extreme or very high-risk landscapes.

High house asset bushfire risk areas

Biolink corridors mapped in these areas are limited to biolink conservation major waterways and Princes Highway. No large-scale terrestrial revegetation or vegetation protection projects are proposed within these areas. Conservation habitat enhancement activities along creek lines will focus on habitat restoration within the riparian corridor.

Table 25. High house asset bushfire risk areas

Small scale conservation management initiatives	Large scale conservation management initiatives – liaison with Municipal fire management planning committee
• Weed and pest animal control including biomass reduction through targeted weed control. Ecological burning and artificial habitat enhancement work. • Terrestrial revegetation limited to isolated planting of spatially separate trees and clumped shrubs to specifications defined in Appendix F1 • Implementation of Council operational open space bushland plans and Melbourne Water work plans.	• Completion of a revegetation bushfire risk site assessment • Liaise with Municipal Fire Management Planning Committee to incorporate local knowledge into riparian planting projects of more than 1000 plants to consider fuel management options to inform design

Moderate to low house asset bushfire risk areas are generally located in the area north of the Gippsland Railway line.

Table 26. Moderate - Low house asset bushfire risk areas

Small scale conservation management initiatives	Large scale conservation management initiatives – liaison with Municipal fire management planning committee
• Weed and pest animal control including biomass reduction through targeted weed control. Ecological burning and artificial habitat enhancement work. • Terrestrial revegetation of less than 2000 trees and shrubs. Revegetation corridors setback at least 150m from dwellings.	• Title protection and fencing projects to protect existing vegetation greater than two hectares • Completion of a revegetation bushfire risk site assessment • Prior to implementing terrestrial revegetation projects greater than 2000 trees and shrubs or areas greater

• Terrestrial revegetation of less than one hectare. • Utilise specifications for isolated planting within the Outer asset protection zone defined in Appendix F1Implementation of Council operational open space bushland plans and Melbourne Water work plans. • Title protection and fencing projects to protect existing vegetation less than 2 hectares •	than one hectare consider fuel management options to inform design including: • Liaise with Municipal Fire Management Planning Committee to incorporate local knowledge into biolink design • Incorporate existing and new firebreaks into design (e.g. roadsides and utility corridors) • Employ a suite of strategic vegetation management works to influence landscape scale fire behaviour (refer Appendix F2) • Where available utilise computer bushfire hazard modelling to assess risk and inform design.

The lowest landscape house risk area is generally located south of Gippsland Railway line

Table 27. ***Lowest landscape bushfire risk areas***

Small scale conservation management initiatives	Large scale conservation management initiatives – liaison with Municipal fire management planning committee
• Weed and pest animal control including biomass reduction through targeted weed control. Ecological burning and artificial habitat enhancement work. • Terrestrial revegetation of less than 3000 trees and shrubs • Terrestrial revegetation of less than two hectare. • Utilise specifications for isolated planting within the Outer asset protection zone defined in Appendix F1 • Implementation of Council operational open space bushland plans and Melbourne Water work plans. • Title protection and fencing projects to protect existing vegetation less than three hectares	• Title protection and fencing projects to protect existing vegetation greater than 3 hectares • Completion of a revegetation bushfire risk site assessment • Prior to implementing terrestrial revegetation projects greater than 3000 trees and shrubs or greater than two hectares consider fuel management options to inform design including: • Liaise with Municipal Fire Management Planning Committee to incorporate local knowledge into biolink design • Undertake site-based assessments to understand local fire behaviour • Incorporate existing and new firebreaks into design (e.g. roadsides and utility corridors) • Employ a suite of strategic vegetation management works to influence landscape scale fire behaviour (refer Appendix F2) • Where available utilise computer bushfire hazard modelling to assess risk and inform design.

All landscape scale revegetation and vegetation protection opportunities that increase vegetation extent within the plan will require completion of a revegetation/vegetation protection bushfire risk site assessment to understand the potential bushfire risk to properties and the broader community.

This requires a project assessment that includes:
- A Site feature assessment
- B Broader landscape assessment
- C Mitigation response to any identified risk

The details of the project assessment are summarised in Table 28, Table 29, and Table 30. The revegetation bushfire risk site assessment will be presented to the MFMPC to inform the opportunities and constraints of a project including whether it is safe to proceed or if the proposal should be modified to appropriately respond to bushfire risk. Results of the assessments will be considered in terms of the guiding management principles (refer to Section 9.1.)

Revegetation/vegetation protection project bushfire risk site assessment

Assessments will be made from 150m from the project site and represent the 'average' description of the features over the assessment area.

Table 28. (A) Features assessed at site scale

Step number	Feature	Details of assessment
A1	Slope	Slope classification can be defined in pages 16-19 of Australian Standards AS3959:2018 Construction of buildings in bushfire-prone areas.
A2	Existing vegetation type	Vegetation classification can be defined in pages 21-29 of Australian Standards AS3959:2018 Construction of buildings in bushfire-prone areas.
A3	Determine existing vegetation connectivity	Identify if the surrounding vegetation is 'connected' or 'spatially separated' to inform decision making on the potential fire behaviour of the immediate landscape. Vegetation that is spatially 'connected' has connected tree canopy, and intact ground storey and understorey. Spatially separated vegetation typically has vertical gaps between the tree canopy and understorey. Horizontal separation of vegetation typically has a minimum gap of 5 metres between the lowest tree branches and the vegetation below.
A4	Distances to dwelling and buildings	Distance in metres to nearest buildings.
A5	Proposed vegetation enhancement works.	Details of proposed revegetation works - number of trees, shrubs and ground-storey species and planting densities

Table 29. (B) Landscape assessment

Step number	Feature	Details of assessment
B1	Metropolitan Bushfire Management Strategy house asset risk area (refer section 9.3.1)	The biolink mapping has areas defined in the MBMS as high, moderate, low and lowest Note Extreme – very high areas are excluded from revegetation enhancement works.
B2	DELWP Biolink risk modelling assessment rating (refer Section 9.3.1)	Identify the DELWP risk modelling assessment which determines if an increase in the biolink corridor extent will either increase the landscape risk or have no impact on landscape risk to assets. The assessment will identify the change in risk to the surrounding landscape because of an increase in vegetation extent.
B3	Current Landscape type assessment	Identify the 'Bushfire management overlay technical guide 2017 DELWP' to identify current bushfire hazard site assessment (refer section 10.1.2)
B4	Landscape type assessment because of the proposal	Identify the 'Bushfire management overlay technical guide 2017 DELWP' to identify proposed bushfire hazard site assessment because of the revegetation proposal (refer section 10.1.2)

Table 30. (C) Revegetation project bushfire risk response

Step number	Feature	Details of assessment
C1	Complete a vegetation connectivity response to address any identified bushfire risks	Where the features and landscape assessment identify a potential increase in bushfire risk, the planting design must be modified to reduce the bushfire risk to the satisfaction of the MFMPC. This could include amending the proposal which considers: • modification of horizontal vegetation structure (i.e., minimum 5m separation between understorey and tree canopy) • modification of vertical connectivity (tree canopy and or understorey layer separate and not touching or installation of fuel breaks.) • increasing the distance of the proposal from existing connected vegetation and/or assets • modification of tree / species selection • orientation of proposal from prevailing winds

10.5 Prioritisation analysis

To support planning decisions, a prioritisation analysis of biodiversity values across Cardinia Shire has been completed. The analysis is based on a framework to prioritise and rank biodiversity assets and remnant habitat within the region and identify their relative conservation significance across private and public land tenures. This prioritisation outputs will allow for not only an improved planning decision framework, but will also support a range of other financial, administrative and operational decisions, grant applications and community advocacy activities. The prioritisation method is presented in Appendix A.

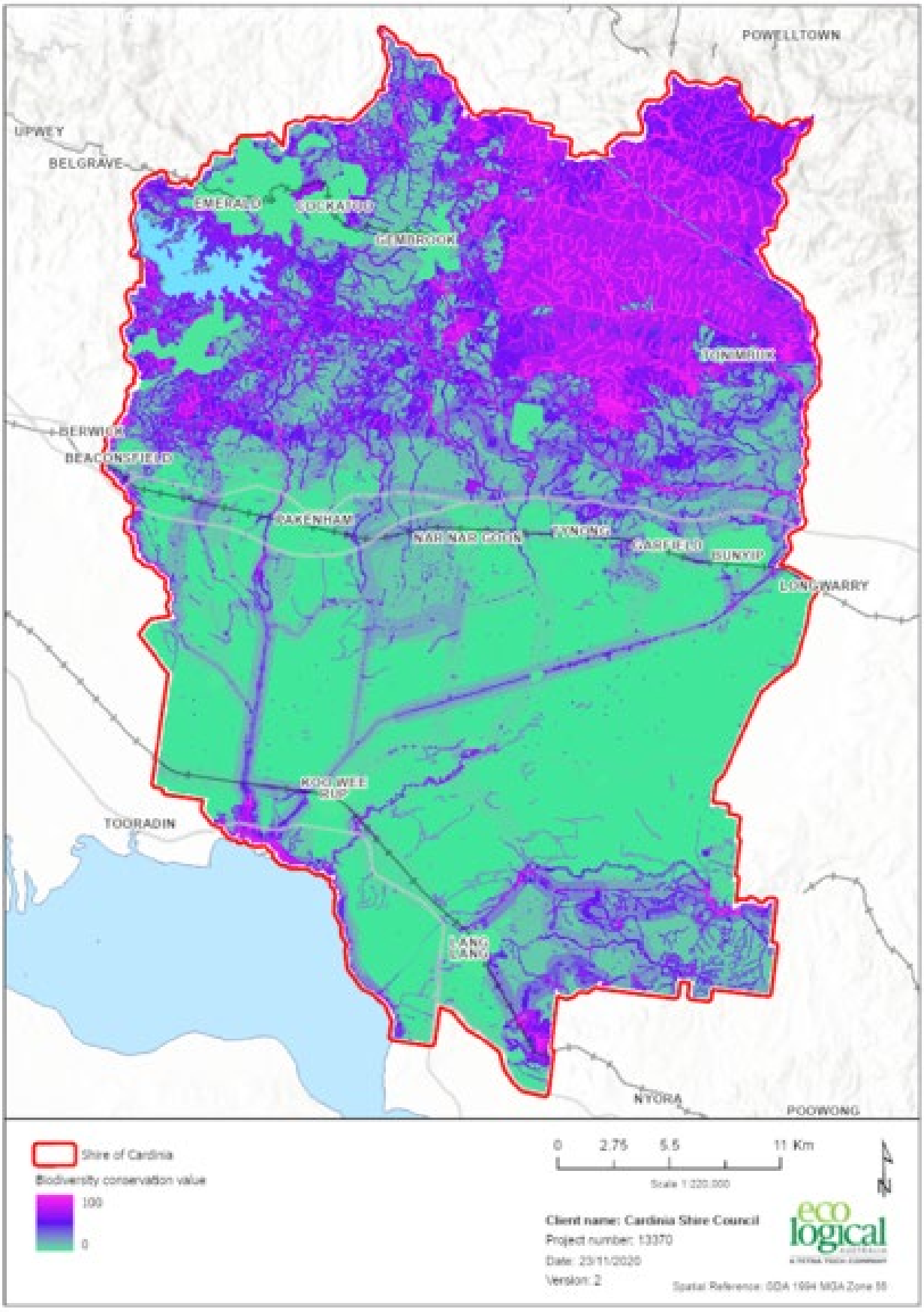
The primary objective of the prioritisation analysis is to identify locations supporting important habitat and linkages. This will inform strategic operational planning to ensure the highest value sites of biodiversity are protected and enhanced.

The analysis combines biodiversity datasets, including those generated as part of the connectivity study, across 10 themes:

- threatened ecological communities
- threatened flora and fauna
- proximity to drainage lines and waterbodies
- conservation areas
- vegetation/ habitat quality
- regional connectivity
- local connectivity
- consolidated vegetation cover
- specified residential township area
- Melbourne's strategic assessment (environmental priorities for select threatened species in the urban growth corridor).

The prioritisation output is shown in Figure 14 and is based on a 100m^2 grid with values ranging between 0 (no biodiversity value) and 100 (highest biodiversity value). As is expected, the highest biodiversity values are associated with areas supporting extensive core habitat within Bunyip State Park and around Cardinia Reservoir. Due to the importance of waterways, these have also been identified as high biodiversity value locations. Vegetation quality areas that scored a biodiversity value of 50 or higher provide an essential and significant contribution to biodiversity connectivity.

Figure 14. Biodiversity conservation priority analysis



The incorporation of regional biolink corridors and localised core habitat and linkages can also be seen in the outputs.

The priority analysis can also be used at a micro scale to identify the conservation significance of individual remnant vegetation sites. This can be beneficial at the property level when:

- identifying the most significant biodiversity assets for property planning
- identifying nearby significant biodiversity assets to connect to.

10.6 Management responses and implementation actions to protect and enhance biolinks

This plan compliments Council's biodiversity conservation and weed management strategies by assisting to inform where and how biodiversity protection and enhancement works should be implemented across the shire. The action plan identifies new actions and supports existing actions, from the BCS and WMS over a 10-year period.

The order of implementation of individual catchment based biolink corridors will be dependent on:

- collaboration with fire management authorities that the biolink will not increase the bushfire risk to people and property
- location in the context of the prioritisation analysis (assessment)
- effectiveness of the implemented biolink
- cost
- local community support.

Two sample biolinks have been developed to illustrate the practical application of conservation and fuel management measures that could be used in landscape scale biolink planning. These illustrations are for general conceptual use. Conservation initiatives are voluntary and will be refined after more detail liaison with the Municipal fire management planning committee, additional site inspection and agreement with all stakeholders.

10.6.1 Sample biolink sites

Sample site 1: Biolink corridor 14 – Toomuc Creek south and Koo Wee Rup

The southern brown bandicoot is listed as endangered. This plan has identified an opportunity to protect, enhance and connect habitat along biolink corridor 14 which will include the enhancement of priority biodiversity nodes '37', '38' and '39' identified in the Biolink Plan.

The priority analysis identifies the site within the top 21% of habitat biodiversity value within the shire.

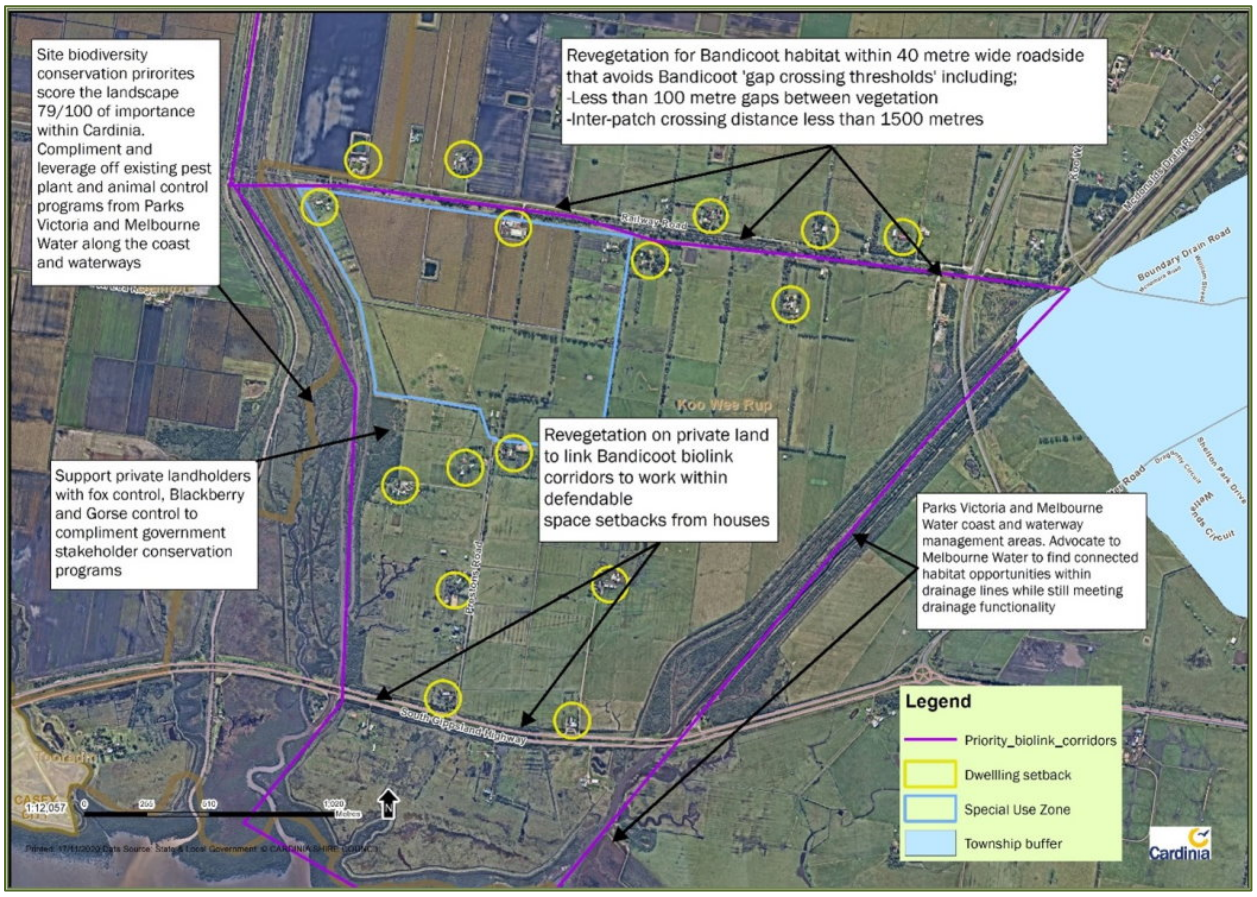
The connectivity analysis has identified remnant vegetation that contributes to core habitat predominately on public land along:

- Bunyip River constructed drainage line
- Cardinia Creek constructed drainage line
- Toomuc Creek constructed drainage line
- Deep Creek constructed drainage line
- Western port Ramsar wetland
- South Gippsland Rail line - Railway Road roadside reserve.

The subject area is located across green wedge zone 1, public use zone 1 and special use zone 1. Conservation and sustainable farming activities are supported within these zones. The site is not registered as an impact area within the *Metropolitan Bushfire Management Strategy*.

Fire behaviour modelling and collaboration with the Municipal fire prevention planning committee will inform the design of revegetation and setbacks from dwellings and farm assets. Figure 15 identifies enhancement and connectivity opportunities to link these remnant habitats through revegetation along private property and the Railway Road-South Gippsland Railway line, the combined width makes up 65 metres. Opportunities may also exist to plant shallow rooted species along the adjacent gas easement to this site.

Figure 15. Conservation project opportunity in Koo Wee Rup



150m revegetation setbacks of swamp scrub ecological vegetation community have identified for existing dwellings to meet fire safety standards outlined for bushfire prone areas at this site. Clumped plantings and the use of artificial habitat structures and rock clusters closer to dwellings. Revegetation should consider the range of habitat opportunities listed in Appendix E. Internal shelterbelts offer the opportunity for pasture protection and habitat opportunities that are part of sustainable farming practises, revegetation opportunities will be limited for the north west corner within the special use zone. Unconstructed government road reservations onsite may also offer opportunities for revegetation.

Fox control is the primary pest animal action to be implemented across the project area. Staged targeted weed control of blackberry and gorse are identified in the drainage lines which are identified as 'priority areas' by Melbourne Water. Rabbit and deer control must also be considered for management.

A Department of Transport bandicoot offset site is located along Bunyip Drainage line which presents an opportunity to bolster priority node 39 and encourage species movement north east of the site. Where maintenance of utility infrastructure necessitates vegetation cleared zones structural connectivity for the species should consider the southern brown bandicoot species parameters including:

- 3-hectare minimum patch size
- breaks in corridor linkages are minimised with gap crossing threshold of no greater than 100m
- inter-patch crossing distance of no greater than 1,500m.

The above specifications represent the outer limits for the species. For connectivity to be functional connectivity should aim for greater connectivity within these habitat standards where possible.

Melbourne Water currently grooms these drainage lines to meet their primary drainage purpose. SBB are likely to utilise the remaining unmown connected habitat along the water's edge, refer to Section 7.4.3. While revegetation is contrary to the drainage function of this asset, in the context of these priority locations, there is value to collaborate with Melbourne Water on the opportunities to provide for superficially wider unmown widths of grass along the water's edge to bolster these priority habitat corridors.

Sample site 2: Biolink corridor 4 – Cardinia Reservoir to Bunyip State Park

The Cardinia Reservoir and Bunyip State Park biolink corridor is one of the most significant fauna linkages within Cardinia Shire. On a local level this corridor links three nodes including Gembrook Bushlands (node 18), RJ Chambers Flora and Fauna Reserve (node 13) and Bourkes Creek bushland (node 10). On a larger scale the corridor represents the narrowest constricted point for fauna egress Bunyip State Park and Churchill, Lysterfield and the Dandenong Ranges. This corridor is identified in the highest 20% of conservation value within the shire.

The corridor represents core habitat for iconic species including greater gliders, eastern yellow robin and the superb lyrebirds. Conservation management objectives support one of the primary purposes of the Rural conservation zone 1 to protect and enhance the natural environment.

The subject area is located within 'low' and 'moderate' impact areas defined in the *Metropolitan Bushfire Management Strategy*. Fire behaviour modelling and collaboration with the Municipal Fire Prevention Planning Committee is a priority prior to commencement of revegetation to inform the precise design of revegetation and setbacks from assets. 98 metres is the maximum defendable space setback distance for forested vegetation at this location within clause 53.02.

Figure 16 identifies strategic fire break opportunities exist along Pakenham Road, Matters Road and Bourkes Creek Road where fuel management actions can be deployed on roadsides, along with additional complementary actions on adjacent private land including (refer to Appendix F2):

- mechanical slashing
- fuel reduction burning
- intensive targeted removal of weed biomass
- thinning of vegetation canopy and understorey
- ecological burning.

Works to achieve the multiple goals of fuel reduction and biodiversity conservation should consider minimising the gap crossing thresholds for low mobility species to be less than 75 metres between patches as a maximum and need to aim to minimise this distance where possible. This will meet connectivity goals for low mobility modelled species such as the greater glider which has a maximum interpatch crossing distance of 150 metres.

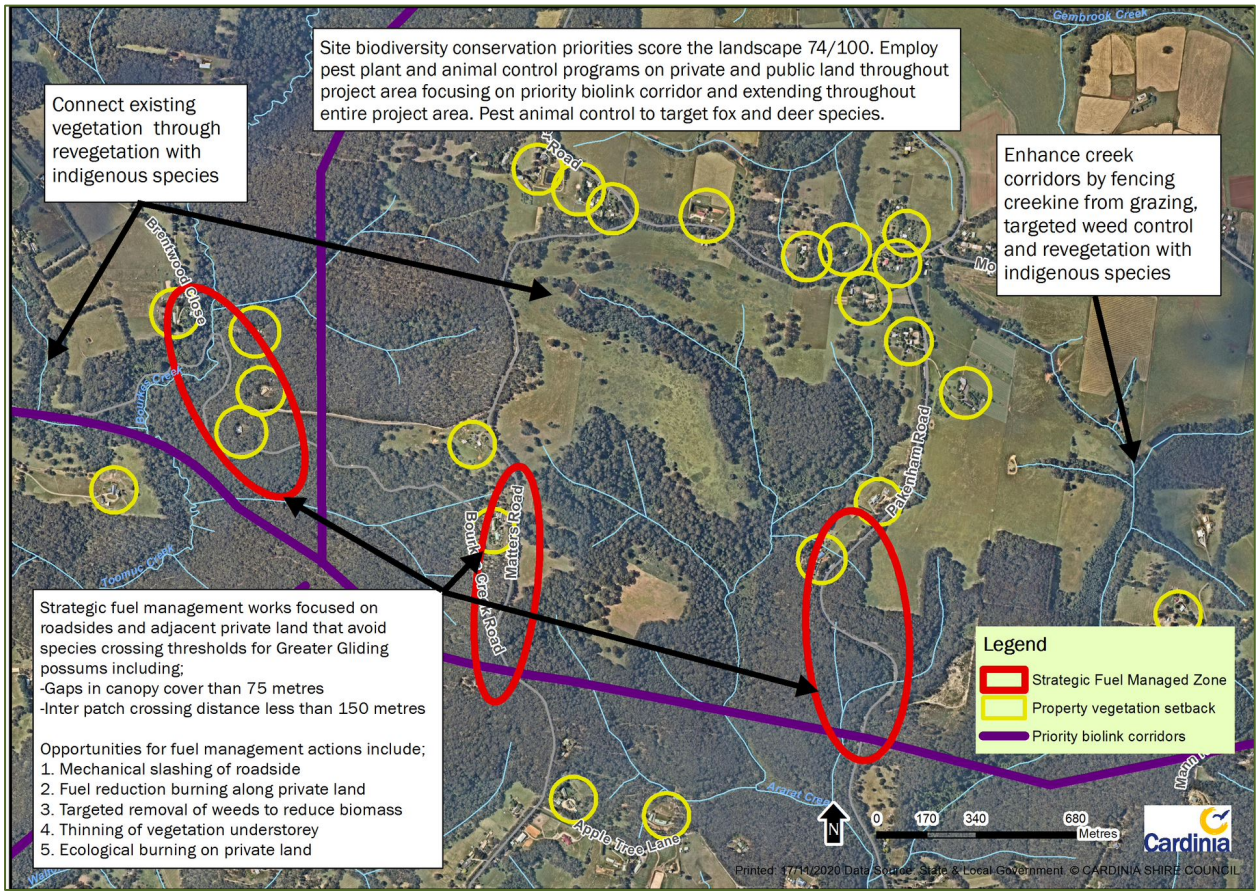
Novel land management opportunities to achieve these multiple goals also include:

- Traditional Owner cultural burning

- Pest animal control of foxes to support Lyrebird habitat and their associated benefit in reduced fuel loads (Maisey, Haslem, Leonard, & Bennett, 2020). Pest animal control should also focus on strategic fire breaks created within the biolink to reduce the predatory pressure in these areas which have lower habitat cover.
- Actively encouraging property owners to develop property management plans (or integrated management plans) are a sound management goal to guide multiple land management outcomes including bushfire safety, agricultural and conservation outcomes. Plans should focus on how they can enhance connectivity for low mobility species to the nearby significant biolink. The protection of creek lines and gullies from grazing will have the most profound benefit to biodiversity. Weed control which will reduce biomass and impact fire behaviour should commence in creeks and gullies and work out from these areas. These waterways have scored as the most significant areas of biodiversity in the priority habitat analysis.

Revegetation which will be informed by the MFMPC expertise should focus on enhancing the narrowest corridor linkage points.

Figure 16. Conservation project opportunity, Upper Pakenham



11 Monitoring and review

A mid-term review of this plan and corridors is scheduled in 2026-27 to ensure content reflects current environmental and statutory planning best practise. A full review of the plan's corridors utilising updated vegetation extent and species distribution mapping will be undertaken in 2032-33.

Understanding the extent and quality of native vegetation and the extent of native fauna on both private and public land will help to inform on the overall health of the natural environment with Cardinia Shire.

There are several actions in the action plan that monitor flora and fauna throughout the shire. The success of the plan's objectives will be informed by the results of these monitoring actions, which are denoted in the action plan with an orange highlight of the action number.

The 15 indicator species identified in Section 6 represent a diversity of fauna species and groups, including those from differing habitat types, lifeform groups, conservation significance, and dispersal and movement capabilities. Understanding the changing extent of species populations will help to inform the health of the natural environment, inform of the success of the plan objectives and build knowledge and learn about species responses to a changing climate.

The establishment of an ongoing shire wide monitoring program for all of the listed indicator species is not economically feasible due to the size of the shire and the resources required to manage to implement such a program. Appendix M addresses the opportunities and constraints of the variety of community, university and Council monitoring programs to understand species health. Utilising the broad range of these monitoring sources in a targeted way to survey species represents an economically efficient use of Council and community resources and provides the community with the opportunity to provide important and meaningful data on the health of our natural environment.

Projects defined in the action plan will ensure continuous improvement in the design of biolink corridors that are effective and safe to people and property. This includes the establishment of two demonstration biolinks to assess the effectiveness of fuel management features which will inform the design of future biolink corridors. Improvements in bushfire behaviour modelling over time will enable land managers to better understand the implications of vegetation management at higher resolutions and more accurately inform safe design of biolinks.

12 Assumptions and limitations

The action plan and *Biodiversity Conservation Strategy* action plan identify a suite of actions which include (a) ongoing research to understand species habitats requirements and (b) identify a communication plan and community awareness program to communicate biolink priorities. A focus of these actions will be to provide information that addresses the following project assumptions and limitations.

Limitations to funding, resources and time confined the selection of three focal species habitats to act as surrogate habitats for a broader range of species. Instances where species, and in particularly threatened species that have specific habitat requirements, such as the Growling grass frog which requires periodic drying of wetlands as suitable habitat, these specific habitats were beyond the available resources to quantify and map within the plan. Heathland habitats were not well represented by these focal species, although these plant communities were confined to pristine areas of Bunyip State Park and were given a generic high habitat score.

Biolink corridors were initially modelled using high resolution mapping of tree canopy and shrub extent to inform the location of nodes and corridors. While local knowledge was able to be applied for some areas, the associated understory vegetation beneath the canopy was assumed to have value for species habitat connectivity. DELWP fire risk modelling also assumes full connected understorey beneath tree canopy mapping. On ground assessments of vegetation quality will need to inform the specific suite of conservation works to realise:

- opportunities for functional and structural connectivity for species which may have been overestimated
- fire hazard ratings which may have been overestimated.

The plan assumes that the suite of works identified in Table 18 will improve habitat which will enable a wide range of species to move through the landscape. This is predicated on the assumption that where habitat is created that species will utilise the biolink asset. This also assumes that conservation actions will be effective. The plan can also not accurately predict individual species responses, the effect from predator species and the implementation of conservation actions in a changing climate.

Precise Victoria-wide scientific data on the focus species and indicator species populations is not known. Understanding base line population numbers to determine the efficacy of conservation actions is therefore complicated and challenging for environmental managers. Actions to monitor species are proposed, but state and local governments do not have funding to thoroughly understand all fauna movements for all landscape contexts.

Corridor alignments were chosen from a range of site-based assessments including, extent of existing vegetation, shortest connectivity options to link core habitats, location of species threats, avoidance of settlement patterns and future development, land reserved for conservation purposes and community support for programs. All these assessments are not a perfect science and involves varying degrees of approximation. The majority of biolink assets are located on private land. The realisation of this plan's objectives is significantly reliant on the community support for the plan.

The best available science for species habitat requirements and gap crossing thresholds was used to map the movement patterns of the three focus species. Limitations on species habitat requirements and movement patters within disturbed landscapes still exists and represents a significant knowledge gap in the project. Numerous environmental variables at each individual site will influence the precise detail of gap crossing thresholds for each species. For example, a reduction in predators will likely enable species to survive in smaller habitats compared to areas that contain predators. While gap crossing thresholds have been identified, the minimum composition and density of 'stepping-stone' habitats across the landscape to link core areas is not precisely known. The action plan and *Biodiversity Conservation Strategy* action plan will seek to focus university

research to further clarify the minimum habitat requirements in a variety of disturbed landscapes to better understand species habitat requirements.

13 Bibliography

Adriaensen F, Chardon JP, De Blust G, Swinnen E, Villalba S, Gulinck H and Matthysen E (2003) The application of 'least-cost' modelling as a functional landscape model. Landscape Urban Planning 64, 233-247.

Agriculture Victoria (2020) Effective shelterbelt design, Agriculture Victoria

APA. (2019, September). Site planning and landscape national guidelines.

AusNet Services. (n.d.). Your guide to planting near electricity lines. Victoria.

Bernadette, S. G. (2016). *Southern Brown Bandicoot Habitat Protection Strategy and Environmental Significance Overlay.* Melbourne. Victoria: Ecology Australia Pty Ltd.

Campbell, A. (2008). *Managing Australian Landscapes in a Changing Climate: A climate change primer for regional Natural Resource Managmeent bodies.* Canberra, Australia: Department of Climate Change.

Cheal, D. (2010). *Growth stages and tolerable fire intervals for Victoria's native begetation data sets. Fire and adaptive management report number 84.* East Melbourne, Victoria, Australia: Department of Sustainability and Environment.

Costanza, R. e. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 253-260.

DELWP. (2017). *Country Fire Authority Riparian land and bushfire. Resource document.* East Burwood, Victoria: State government of Victoria.

Fox, M. D. (1986). The effect of fire frequency on the structure and floristic composition of a woodland understorey. *Australian Journal of Ecology*.

Gill, A. M. (1999). *Australia's biodiversity responses to fire: plants, birds and invertebrates.* Canberra: Department of the Environment and Heritage.

Gill, M. (1996). *How fires affect biodiversity.* Retrieved from Australian National Herbarium: https://www.anbg.gov.au/fire_ecology/fire-and-biodiversity.html

Gott, B. (2005). Aboriginal fire management in south-eastern Australia: aims and frequency. *Journal of Biogeography*, 1203-1208.

Gould, J. M. (2007). *Field Guide - Fire in dry eucalypt forest: fuel structure, fuel dynamics and fire behaviour .* Canberra: Ensis-CSIRO.

Kenny, B. S. (2004). *Guidelines for ecologically sustainable fire management.* NSW Biodiversity Strategy, NSW National Parks and Wildlife Service.

Morgan, G. T. (2020). Prescribed burning in south-eastern Australia: history and future directions. *Australian Forestry*, 4-12.

Services, I. S.-P. (2019). *Report of the Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on the work of its seventh session.* Paris: United Nations.

Tran C., W. C. (2000). *The Review of Current Knowledge and Literature to Assist in Determining Ecologically Sustainable Fire Regimes for the South East Queensland Region.* Griffith University.

VicRoads. (2016, May). VicRoads Tree Policy - revision 2.0.

Victorian Environmental Assessment Council. (2013). *Yellingbo Investigation - Final report.* Melbourne: VEAC.

Victorian Environmental Assessment Council. (2013). *Yellingbo Investigation Final Report.* Melbourne, Victoria: Victorian Environmental Assessment Council.

14 Action plan

15 Appendices

Appendix A: Biolink study scope and methods
Appendix B: Existing strategies, plans and connectivity studies
Appendix C: Stakeholder workshop – summary of outcomes
Appendix D: Indicator species standards
Appendix E: Functional connectivity improvements
Appendix F: Opportunities to create safer landscapes
Appendix G: Assessment of unconstructed roads
Appendix H: Connectivity implementation mapping
Appendix I: Legislative summary
Appendix J: Summary of bushfire risk measures
Appendix K: Options for the safe design of riparian areas from assets
Appendix L: Estimating vegetation setbacks for riparian plantings
Appendix M: Summary of efficacy of Council, community and educational research biodiversity monitoring programs