Biodiversity Sensitive Urban Design @ Glen Junor

A draft report prepared for Trent McCamley and Partners by

Prof Sarah Bekessy
Dr Georgia Garrard
Sarrah Hurley
Katherine Berthon

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Executive Summary

Biodiversity sensitive urban design (BSUD) represents a fundamentally different way of planning for and designing urban developments. Biodiversity sensitive urban design aims to create urban environments that make a positive onsite contribution to biodiversity through careful planning and innovative design and architecture. Rather than considering biodiversity as a constraint - a 'problem' to be dealt with - biodiversity is seen as an opportunity and a valued resource to be preserved and maximized at all stages of planning and design.

Reframing biodiversity (or nature - a more commonly understood term) as a positive benefit to be maximized means moving away from 'offsetting' as the solution. Under this approach, vegetation that is cleared in urban areas may be offset most cheaply somewhere else, often far from the site of impact. This is a poor solution in an urban context because it will fail to provide nature in the places where people can benefit most from interacting with it, and, at the same time delivers questionable ecological outcomes. In contrast, BSUD seeks to care for and bring back nature in urban environments - we call it 'onsetting'- in the places people live, work, play and travel. Aside from improving the fate of native species and ecosystems in the city and surrounds, there are numerous co-benefits of implementing BSUD that are critical to the future of liveability of cities. These include: providing important community health and well-being benefits, enhancing resilience to extreme temperatures and weather events, re-enchanting residents with nature, connecting with Indigenous history and culture, and delivering economic advantages; for example, through improved property values and more active and productive business districts.

BSUD links urban form to the persistence of biodiversity to ensure a scientifically-driven design process, providing a flexible framework for developers and planners to consider biodiversity alongside socio-economic considerations, early in the development process. The decision process involves documenting biodiversity values, identifying biodiversity and development objectives, identifying potential BSUD actions, assessing those actions and reaching a decision regarding a design for the site that best meets biodiversity and socio-economic objectives.

BSUD for the proposed Glen Junor development will help protect existing plants and animals on the site and has the potential to substantially improve the extent and condition of regionally-significant ecological communities. Onsite biodiversity gains will be achieved through:

- Identifying, protecting and enhancing remnant vegetation, which will be maintained in actively managed reserves.
- Enhancing habitat across the site by retaining and protecting large old trees and increasing native plant diversity and complexity through revegetation.
- Improving the probability of persistence for listed/protected species and ecosystems.
- Re-introducing species to the site that are assumed to have become locally extinct in recent times, either passively, by improving habitat and providing critical resources and waiting for the species to return by its own devices, or actively, by translocating species from other locations into recreated or improved habitat.
- Using innovative architecture and design to ensure that the urban matrix itself can deliver important habitat and resources for target species, for example through adding green infrastructure and incorporating critical resources and habitat analogues, such as habitat walls.
- Facilitating dispersal of target species by adding animal movement infrastructure and establishing habitat connectivity corridors through private and public land.
- Addressing key threats that emanate from the built environment, for example by landscaping with native plants, establishing pet containment programs, reducing runoff and nutrient loads through vegetated swales and rain gardens and reducing light and sound pollution.
- Facilitating natural ecological processes, such as pollination and fire, while mitigating safety concerns.
- Improving the potential for positive human-nature interactions by facilitating local stewardship of biodiversity (for example through wildlife gardening programs), providing 'cues to care', creating opportunities for positive interactions with nature and addressing potential conflicts between biodiversity, safety objectives or potential disservices.

In this report, we provide detail of the approach and process of undertaking BSUD for the proposed Glen Junor, including general recommendations for biodiversity objectives and actions.

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What is Biodiversity Sensitive Urban Design?

Biodiversity Sensitive Urban Design (BSUD) is a protocol for urban design that aims to create suburbs and towns that are a net benefit to native species and ecosystems through the provision of essential habitat and food resources (Garrard et al. 2018). BSUD represents a new approach to urban biodiversity conservation that seeks to achieve biodiversity benefits on site, within urban environments. This is in contrast to the standard offsetting approach, which reduces the opportunity for urban residents to engage with nature and, at the same time, delivers questionable ecological outcomes (Maron et al. 2016).

BSUD links urban design to measurable biodiversity outcomes, providing a flexible framework for developers and planners to consider biodiversity alongside socio-economic considerations, early in the development process. The decision process underpinning BSUD is shown in Figure 1. Briefly, the process involves documenting biodiversity values, identifying biodiversity and development objectives, identifying potential BSUD actions, assessing those actions and reaching a final decision regarding a design for the site that best meets biodiversity and socio-economic objectives.

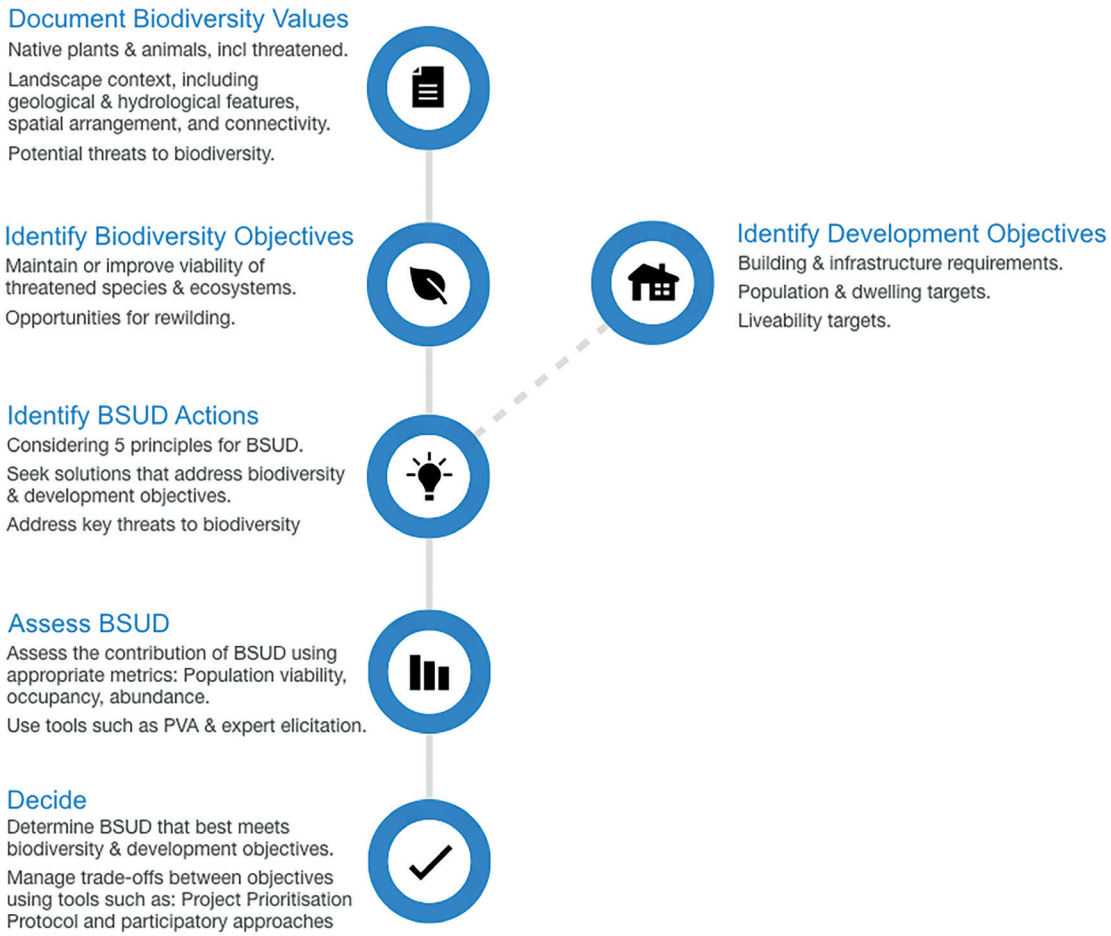


Figure 1. Biodiversity sensitive urban design describes a decision-making process in which biodiversity objectives are considered alongside other socio-economic development objectives, early in the planning process. From Garrard et al. (2018)

To achieve onsite biodiversity benefits, BSUD must mitigate the detrimental impacts of development, while encouraging community stewardship of biodiversity, facilitating positive human–nature interactions. We have distilled relevant ecological knowledge for addressing the impacts of urban development into five BSUD principles (Garrard et al. 2018):

Protect and create habitat

New developments can be planned to avoid habitat loss by prioritizing development in areas of low ecological value (Bekessy et al. 2012). Retaining and protecting existing vegetation during the development process can also be beneficial for biodiversity. Habitat can be enhanced or created in existing urban areas by using native plant species and increasing vegetation complexity (Ikin et al. 2015), adding green infrastructure (Williams et al. 2014) or incorporating critical resources and habitat analogues, such as habitat walls. Residential gardens can be significant habitat, so residential wildlife gardening programs can make a valuable contribution to biodiversity (Mumaw & Bekessy 2017).

Facilitate dispersal

Dispersal can be facilitated by adding animal movement infrastructure (Taylor & Goldingay 2012), or establishing habitat connectivity corridors through private and public land (Goddard et al. 2010). Care should be taken to avoid inadvertently facilitating the spread of invasive weeds and pests.

Minimise threats and anthropogenic disturbances

The impact of weeds and exotic predators can be reduced by landscaping with indigenous plants and establishing pet containment programs (Ikin et al. 2015). Increased runoff and nutrient loads can be mitigated by vegetated swales and rain gardens, which also deliver biodiversity benefits. The impact of noise and light pollution can be mitigated by sound barriers (although take care that this does not affect dispersal), temporary road closures and dimming or reconfiguring street lights (Gaston et al. 2012).

Facilitate natural ecological processes

The disruptive effects of urban development on natural cycles, ecological processes and disturbance regimes (Grimm et al. 2008) can be mitigated by providing adequate resources for target species, protecting and enhancing pollinator habitat, and planning to safely enable natural disturbance events such as fire and flooding.

Facilitate positive human-nature interactions to enhance biodiversity stewardship

Cities and towns are human environments and public engagement is key to successful conservation. Urban design can help facilitate local stewardship of biodiversity by providing “cues to care” (Nassauer 1995), creating opportunities for positive interactions with nature, and addressing conflicts between biodiversity and safety objectives (Ikin et al. 2015) or potential ecosystem disservices.

Why Biodiversity Sensitive Urban Design?

Biodiversity sensitive urban design is designed to bring back and care for nature in the places where people live, work, play and travel. An emerging body of research is revealing that this notion of ‘every day nature’ plays a critical role for the future livability of cities and towns, beyond concerns for biodiversity. The numerous co-benefits of implementing BSUD are highlighted in Figure 2 and are outlined below.

Community health and wellbeing

Urban nature delivers a remarkable range of human health and well-being benefits. In 1984, Roger Ulrich published the first study to suggest these benefits, when he chanced upon a link between improved surgical healing times and a view of nature. Since then, numerous studies have revealed a multitude of benefits to interacting with nature in our daily lives. Children living in streets with trees will have lower incidence of asthma (Lovasi et al. 2008) and allergies (Hanski et al. 2012) and those with nature in their schoolyards will have improved cognitive development (Dadvand et al. 2015) and lower incidence of ADHD (Faber Taylor & Kuo 2011). Adults are less likely to die from heart disease, diabetes and cancer (Kuo et al. 2015). If you are lucky enough to have regular contact with nature, you will sleep better, have reduced stress levels, reduced risk of poor mental health, a better social life and improved self-esteem and empowerment (Kuo et al. 2015). Indeed, you are more likely to live longer and have better general health and well-being in a city with more biodiversity.

Future proofing cities in the face of climate change

Urban environments are warmer than adjacent suburban and rural environments due to the ‘urban heat island effect’ (Riswan et al. 2008). This pervasive global phenomenon exacerbates the major threat that heat stress poses to human health and well-being in many cities. The heat wave and fires in Melbourne 2009 that contributed to the deaths of over 500 people is a potent example. Climate change will further aggravate the impacts of the heat island effect, increasing the severity and frequency of extreme weather events (IPCC 2012). Rising sea levels, variable rainfall patterns and destructive cyclones will continue to threaten homes and medical infrastructure whilst compromising the supply of energy and fresh, potable water. In turn, these impacts increase the risks of infectious diseases and mental disorders (WHO 2015).

Vegetation in and around cities, towns and regional centres can deliver a range of ecosystem services critical for climate change adaptation and mitigation. Through evapotranspiration, shading and reflectance, the vegetation present in green spaces can cool these environments substantially, at least partly ameliorating the heat island effect (Bowler et al. 2010). Greening interventions have the potential to cool urban centres by up to eight degrees in summer (Doick 2013), importantly reducing overnight temperatures, which is a key determinant of heat-related mortality (UK Dept Health 2018). Vegetation in cities and towns can provide other important climate change adaptation services including alleviating the impacts of flooding by reducing peaks in storm-water runoff (Xiao & McPherson 2002) and providing shelter from extreme weather events (Abdollahi & Ning 2000). Finally, vegetation can play a significant role in mitigating climate change impacts by sequestering greenhouse gases (cities can store as much carbon per unit area as tropical forests (Churkina et al. 2010)) and reducing energy consumption for cooling and heating (Coutts et al. 2007).

Cities are hotspots for threatened species

Cities around the world host numerous threatened plant and animal species. Indeed, threatened species are often over-represented in cities, which tend to be located in areas of naturally high biodiversity (Luck 2007). In a recent survey of Australian cities and towns, more than three times as many threatened species were found per unit area than in rural areas (Ives et al. 2016). Some species are found only in urban environments, while others rely on cities for key food and habitat resources. The future of many threatened species will depend on actions to accommodate their needs within urban boundaries, making cities and towns justifiable locations for serious investment in nature conservation for its own sake.

An emerging body of evidence suggests that green spaces with a higher diversity of species deliver greater health, well-being and social benefits than less diverse spaces (Fuller et al. 2007). Many of the positive benefits of urban greening arise from interaction with structurally-complex and biodiverse green space. Furthermore, structural and species diversity will improve the robustness of green infrastructure in the face of threats from extreme weather events, disease and insect predation. Hence it's not just 'greenness', but also 'biodiversity' that should be the focus of urban re-naturing strategies.

Re-enchanting people with nature

Miller (2005) describes the "extinction of experience" that has occurred around the world, as people living in cities and towns have become increasingly disconnected from the natural realm: children who don't know where milk comes from, adults who can identify hundreds of company logos, but only a handful of native plants, and adolescents who are less able to identify a bird by its call than the type of automatic weapon by its report. This trend is all the more significant given the increasingly urbanizing world that we live in; it's predicted that 66% of the world population will live in cities by 2050 (United Nations 2014).

Creating opportunities for every day doses of nature through better urban design provides an unparalleled opportunity to re-enchant people with biodiversity, restore the frequency and strength by which human city-dwellers interact with plants and animals, create sense of place and expose urban residents to the myriad health and well-being benefits provided by nature. These interactions may be passive, or may involve caring for, restoring and monitoring nature. They may further provide a common purpose that builds a sense of community and belonging. As an example, wildlife gardening programs can generate enormous amounts of social capital (Mumaw & Bekessy 2017). For children, re-enchantment with nature could be key to solving the increasing incidence of pervasive behavioral problems (Louv 2005). Critically, engaging people with nature in where they live, work and play will be key to generating the social license for biodiversity conservation in

Connecting with Indigenous history and culture

Cities and towns often occur in locations where Indigenous cultures have traditionally thrived, frequently alongside high levels of biodiversity (Mercer et al. 2015). These are often places where natural resources have been used and cultivated in a sustainable way for thousands of years. Indeed, many ecosystems rely on traditional land management practices to maintain high levels of diversity; Aboriginal fire regimes in Australia are a good example (Bird et al. 2008). Traditional knowledge of landscape pattern and processes, hydrological cycles and species and ecosystem management are highly relevant to town planning. Many modern cities owe their foundations to historical Indigenous settlements (for example, Mexico City is founded on the capital of the Aztec Empire, Tenochtitlan)). Yet Indigenous knowledge, past and present, is rarely utilized in urban planning processes (Stuart & Thompson-Fawcett 2010).

The potential for engaging Indigenous people in the planning, design, implementation and governance of urban re-naturing is substantial. In practice, this could mean using culturally significant species, such as traditional foods and medicines (eg. engagement with Rasta herbalists in Cape Town to cultivate medicinal plants in communal gardens), reflecting Indigenous understanding of landscape and seasons in urban design (eg. incorporating the Wurundjeri seven seasons in playground design in Princes Park), developing programs such as 'caring for country' and Indigenous ranger programs to engage Indigenous populations in the management of urban parks (City of Melbourne 2016), and prioritizing Indigenous groups in urban governance (eg. The city council of Auckland, New Zealand has an independent Maori Statutory Board and Pacific People Advisory Council to ensure the consideration of Maori and Pacific Islander interests, priorities and values within urban planning (Mercer et al. 2015)).

Engagement of this kind may present a way of improving lives and retaining traditional knowledge for urban Indigenous populations (Mercer et al. 2015). Furthermore, traditional knowledge has proven to contribute to higher quality of urban life and could improve the success of initiatives to generate 'every day nature'. Connecting urban residents to Indigenous history and culture through urban re-naturing programs has the potential to create respectful attitudes and pride in local Indigenous knowledge.

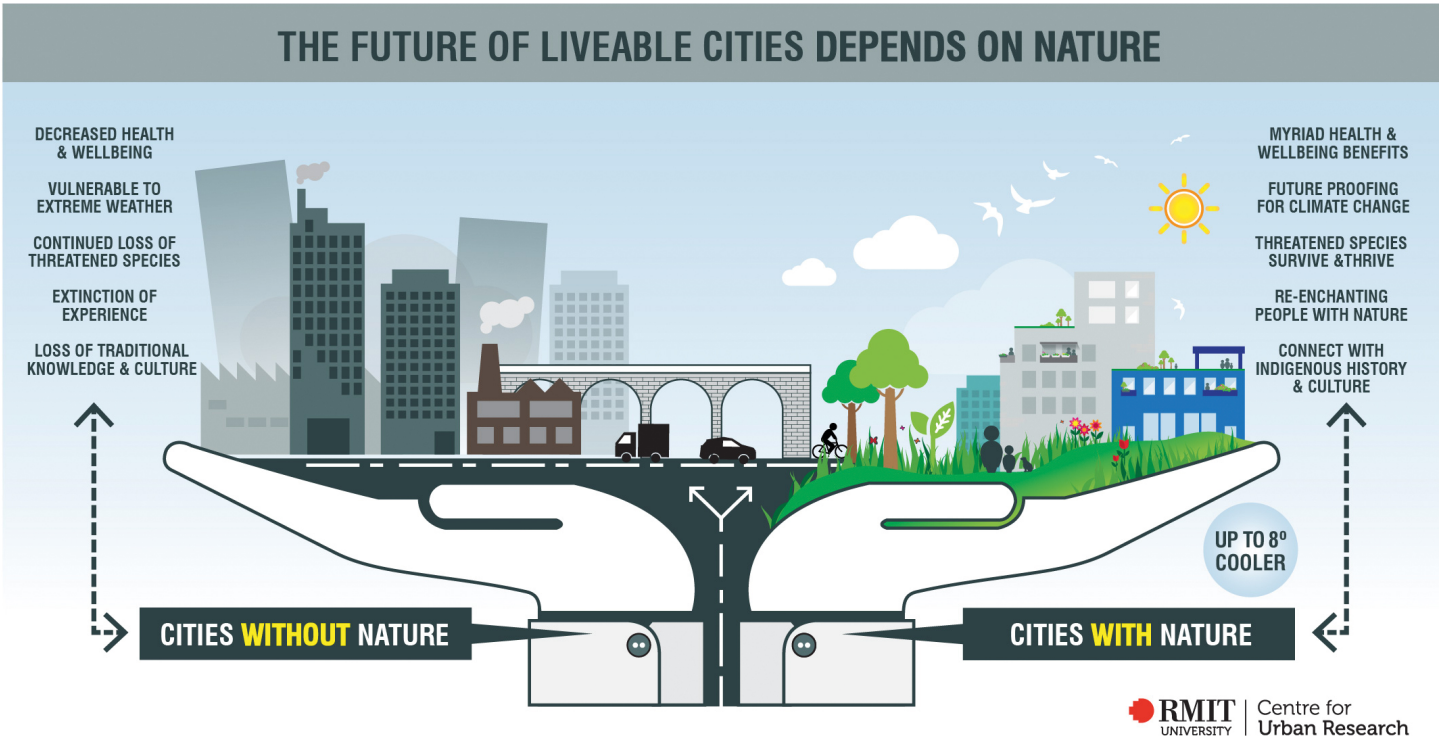


Figure 2. An emerging body of research is revealing the critical role of 'every day nature' for the future livability of cities. Improving contact with nature in cities is a compelling public health intervention, with an impressive array of benefits to health and well-being. Furthermore, vegetation in and around cities can deliver a range of ecosystem services critical for climate change adaptation and mitigation. Cities are often hotpots for threatened species and are justifiable locations for serious investment in nature conservation for its own sake. Creating 'every day nature' has the potential to re-enchant people with nature and connect urban residents to Indigenous history and culture (reproduced from Bekessy et al. in review).

Financial benefits

There have been numerous compelling studies of the economic case for urban greening. Urban greening initiatives have been shown to improve property values, reduce maintenance costs, protect drainage systems and reduce energy consumption. Greening in business districts increases community pride and positive perceptions of the area, drawing customers to businesses and increasing retail activity, while at the same time increasing workplace productivity. The potential for tourism operations, such as wildlife sanctuaries, fenced areas for reintroductions of threatened species and education facilities is substantial. To highlight just a couple of examples of studies demonstrating these links, in 2007, the Financial Review documented a study that found that for every $1 invested annually in planting and maintenance of New York City's 592,000 street trees, $5.60 worth of environmental and property value benefits ensued. Likewise, a PhD candidate in the School of Geography Planning and Environmental Management at the University of Queensland, made a similar study for her PhD, of the local government area of the City of Brisbane. She found that in calendar year 2010, Brisbane's street trees generated property-value benefits of $29 million – more than twice the cost of planting and maintaining them.

Alignment with key policies

The objectives of BSUD are aligned with policies at all levels of Government, including the Victorian Government Biodiversity Strategy (2017-2037), which calls for 'Increased opportunities for all Victorians to have daily connections with nature' and the Victorian Public Health and Wellbeing Plan which recognises that 'interacting with nature contributes to a reduction in chronic disease risk factors, increases social inclusion and builds strong communities'. At the Federal level, the Australian Government Nature Strategy (2018-2030) includes a specific goal to 'enrich cities and towns with nature'. At the local government level, The Macedon Ranges Shire recognises that it is responsible for 'Unique biodiversity values' and is developing a Biodiversity Strategy in 2018 that seeks to 'protect and enhance ecological values across the Shire' including through the development of "planning provisions and priority actions for community engagement, on-ground works and monitoring" (Macedon Ranges Shire 2018).

Biodiversity Sensitive Urban Design at Glen Junor

This section provides an overview of how the BSUD process presented in Figure 1 could be applied to the proposed Glen Junor Vision. We focus on the first three steps; a thorough assessment of the full range of benefits provided by BSUD is a significant quantitative undertaking and beyond the scope of this report, however we have made some qualitative assessments where possible based on prior knowledge or available information.

Step 1 - Document biodiversity values

The proposed development at Glen Junor is located within an area of high ecological significance and value, as highlighted in the biodiversity assessment report (Practical Ecology, 2018). The biodiversity assessment notes the occurrence of important scattered habitat trees, and regionally significant ecological communities, including Plains Grassy Woodlands, Plains Sedgy Wetland and Riparian Woodland.

Step 2 - Identify biodiversity objectives

Objective 1. Deliver an on-site net gain in biodiversity

Biodiversity sensitive urban design goes beyond what is currently required by state and national legislation and policy. Specifically, it requires proponents to consider how their urban environment can deliver an on-site net gain for biodiversity. There are two key reasons for this. First, like many cities around the world, Melbourne carries an extinction debt (Hahs and McDonnell 2012). An extinction debt exists when there is a delay between an action occurring (eg. habitat loss) and the ultimate ecological impact. This delay can be relatively short, or operate over periods of hundreds of years. In practical terms, an extinction debt means that even if we were to protect all remaining habitat now, some species would still go extinct. Therefore, in order to reverse the trajectory for biodiversity, we must seek to find new ways to add to existing habitat, including through enhancement of habitat within urban environments. Second, as described above, there are compelling social, environmental and economic reasons for retaining and enhancing biodiversity on-site within urban environments. Facilitating experiences in nature for urban residents can lead to a remarkable range of health and wellbeing benefits (Shanahan et al. 2015; Cox et al. 2017). Reconnecting urban residents to nature is also thought to contribute to biodiversity through improved attitudes towards biodiversity and its protection (Soga & Gaston 2016). Standard conservation practices such as protecting remnant populations *in situ*, and offsetting unavoidable biodiversity losses are not adequate to mitigate the impacts of urban development on biodiversity or reconnect urban residents with nature. A new approach is required to deliver on-site biodiversity gains and nature in the places where people live, work and play; biodiversity sensitive urban design.

Spotted pardalote, *Pardalotus punctatus punctatus*. Photo by Patrick Kavanagh, reproduced under Creative Commons licence [CC BY 2.0] via Flickr.

Objective 2. Improve the probability of persistence for listed/protected species & ecosystems

BSUD at Glen Junor would seek to enhance the probability that threatened species and ecosystems could persist *on-site* by:

- Identifying, protecting & enhancing high quality remnants/habitat;
- Addressing key threats that emanate from the built environment; and
- Providing key food, habitat and dispersal resources within the built environment.

In their biodiversity assessment of the site, Practical Ecology (2018) note the presence or likely presence of numerous potential target threatened species and ecosystems (Table 1). BSUD would seek to improve the outcomes for these ecological attributes on site, by extending concepts of habitat to include the built form and by considering how urban design can be used to foster environmental stewardship within residents.

Table 1. Recorded or likely extant species and ecosystems that would be suitable targets for biodiversity sensitive urban design at Glen Junor.

Species/Ecosystem
Ecosystems Plains Grassy Woodland • Overstorey includes a large Swamp gum, *Eucalyptus ovata* Plains Sedgy Wetlands Riparian Woodlands • Overstorey includes large River red gums (*Eucalyptus camaldulensis*), Yellow box (*Eucalyptus melliodora*), and Swamp gum (*Eucalyptus ovata*), and a smaller Manna gum (*Eucalyptus viminalis*).
Species Austral crane's-bill, *Geranium solanderi var. solanderi s.s.* Basalt tussock-grass, *Poa labillardieri var. (Volcanic Plains)* Matted flax-lily, *Dianella amoena* Pale swamp everlasting, *Coronidium gunnianum* Large flower crane's-bill, *Geranium sp. 1* Clover glycine, *Glycine latrobeana* Brown toadlet, *Pseudophryne bibronii* Southern water skink, *Eulamprus tympanum tympanum* Yellow-tailed black cockatoo, *Calyptorhynchus funereus* Nankeen kestrel, *Falco cenchroides* Black falcon, *Falco subniger* Superb fairy-wren, *Malurus cyaneus* Spotted pardalote, *Pardalotus punctatus punctatus* Brown treecreeper, *Climacteris picumnus victoriae* Latham's snipe, *Gallinago hardwickii* Nankeen night heron, *Nycticorax caledonicus hillii* Golden sun moth, *Synemon plana*
Individual scattered trees Large scattered trees • Yellow box, *Eucalyptus melliodora* • Swamp gum, *Eucalyptus ovata* Small scattered trees • Yellow box, *Eucalyptus melliodora* • Swamp gum, *Eucalyptus ovata* • River red gum, *Eucalyptus camaldulensis*

Objective 3. Bring target species back to Glen Junor

Bringing lost native species back to Glen Junor is a third key objective for BSUD. Glen Junor is to be located in an area that has been subject to significant human modification since European settlement. As a result, many native species have been lost from the system. Biodiversity sensitive urban design offers an opportunity for 'rewilding' or restoring lost species to an area, either passively, by improving habitat and providing critical resources and waiting for the species to return by its own devices, or actively, by translocating species from other locations into recreated or improved habitat (which may or may not be novel).

Top: Matted flax-lily. Photo by Takver, reproduced under Creative Commons licence [CC BY-SA 2.0] via Flickr.
Bottom: Latham's snipe. Photo by Ed Dunens, reproduced under Creative Commons licence [CC BY 2.0] via Flickr.

Target species for rewilding include:

- Golden sun moth, *Synemon plana*, a nationally-threatened invertebrate species with a high likelihood of being present on the property;
- Matted flax-lily, *Dianella amoena*, a nationally-threatened plant species with a high likelihood of being present on the property, in conjunction with one of its key pollinators, the Blue banded bee, *Amegilla sp.*, a charismatic species with significant potential to bridge natural and domestic boundaries (Mata et al. 2016; See Box 1); and
- Latham's snipe, *Gallinago hardwickii*, a migratory water bird that is vulnerable in Victoria, but has been recorded in wetter areas of the site as recently as 2016.

Objective 4. Enhance/create biodiversity stewardship in Glen Junor residents

The fourth objective we have identified for BSUD at Glen Junor is to ehance (or create) a sense of stewardship for biodiversity and nature within Glen Junor residents. This includes stewardship at the local scale - for example, stewardship of local parks and private and semi-private green spaces - and also at the regional scale, which will be important given the size and diverse land uses proposed at Glen Junor.

BSUD provides an important opportunity to address the ever-increasing disconnection of people from nature. This 'Extinction of Experience' is associated with a negative cycle that links the disconnection from nature to a growing apathy towards nature and ongoing biodiversity loss (Pyle 1978; Miller 2005; Soga & Gaston 2016). Helping to reconnect people with nature, by embedding it into the places where people live, work and play, may help to enhance biodiversity stewardship locally and more broadly.

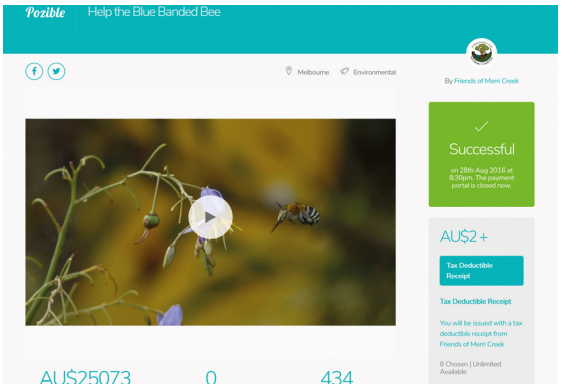
Box 1. Blue-banded bee as a target species for rewilding

Blue-banded bees are a beautiful and charismatic group of native bees in the genus *Amegilla*. A unique blend of characteristics makes them particularly suitable for rewilding (Mata et al. 2016).

Blue-banded bee visiting a native flax-lily, *Dianella* sp. Photo: Luis Mata

1. *Blue-banded bees provide an important ecosystem service.* Blue-banded bees utilize a specific pollination method – buzz pollination – which is more effective for pollinating many native flowers. This includes flowers of the flax-lillies in the genus *Dianella*, which are commonly found in native grasslands, and whose berries are an important food source for birds and lizards. The nationally-endangered Matted flax-lily, *Dianella amoena*, is thought relatively likely to occur on the Glen Junor site (Practical Ecology 2018).

2. *Blue-banded bees can bridge the gap between public & private realms.* In addition to their role in pollinating native species, blue-banded bees are effective pollinators of many garden species, including amenity species such as lavender, and urban crops such as tomatoes and sweet basil. In addition, blue-banded bees are highly visible and easily recognizable, making them ideal for public engagement. Indeed, the significantly capacity for these species to generate public enthusiasm is illustrated in the success of a recent crowdfunding campaign hosted by the Friends of the Merri Creek, which rapidly raised more than $25,000 to support the planting of 'Bee Cafes' – plantings of nectar-rich wildflowers in public and private spaces – to better connect populations of the endangered Matted flax-lily, *Dianella amoena*, in northern Melbourne.



Screen grab of Friends of Merri Creek's successful blue-banded bee crowdfunding campaign

Blue-banded bees will use novel and garden resources. Photos: (L, C) Max Pixel; (R) Bees Business.

3. *Blue-banded bees will utilize novel habitats and resources.* Because blue-banded bees will collect nectar and pollen from a wide range of native and introduced flowering plants, private gardens and ornamental public plantings can provide important habitat and resources. Blue-banded bees are solitary nesting bees; analogue nesting habitats can be easily and successfully incorporated into urban areas by incorporating mudbrick features with specially drilled holes.

Step 3 - BSUD to achieve objectives

In practice, the requirements of individual species and ecosystems as they relate to each of the five BSUD principles would need to be considered in detail. In this report, following our brief assessment, we make the following initial and broad recommendations for BSUD at Glen Junor.

Design for Biodiversity

A key objective for biodiversity sensitive urban design is to create environments that deliver a net gain in biodiversity. This means that it is necessary to protect the biodiversity values that are present (no net loss), whilst also adding to them to create opportunities for a net gain. A recent review of urban biodiversity found that the total cover of habitat was an important predictor of species richness (Beninde et al. 2015), so protecting existing habitat is an important first step.

1. *Protect existing habitat tress, including scattered trees, and use these as a focal point for revegetation*

Large and hollow-bearing native trees, including scattered trees, provide critical habitat for many native bird and mammal species, including charismatic species like yellow-tailed black cockatoos. In order to deliver a net gain in biodiversity, these remnant trees will need to be protected (Ikin et al. 2015). Typically, this requires protecting (via fences or other barriers) the root zone of the trees (an area that is, at minimum, as large as the canopy of the tree) from compaction during construction and inhabitation phases. Preferably, the protected area would be large enough to allow for some natural regeneration of these trees, in order to ensure the habitat trees of the future.

Woody stags and dead hollow-bearing trees, also provide important habitat, including as perching points for birds of prey. In higher-use areas, risks associated with falling limbs can be mitigated by enhancing the mid-layer to deter people from lingering underneath.

2. *Protect and enhance existing vegetation*

Any existing vegetation should be protected and enhanced. This would include retaining exotic tree and shrub species, unless they pose a significant invasion risk, as these may be providing critical foraging habitat and protection for native species. At the very least, protection of remnant vegetation would include implementing and enforcing an appropriate ecological management plan from as early as possible in the process, physical protection of habitat zones during the construction phase, protection from threats from final land use, and ensuring that appropriate buffers are implemented on the outside of remnant patches.

Existing vegetation can be enhanced through revegetation to improve grassy understoreys and wetland habitats, as well as revegetation to bring tree densities in woodland habitats in line with typical densities for extant EVCs.

3. *Protect and create habitat*

BSUD would also seek to enhance and create habitat. This can be achieved in existing natural areas (for example, through the addition of rocks and other microhabitats for species like the fat-tailed dunnart) or within the built environment itself.

General recommendations about enhancing and creating habitat in urban environments include:

- Enhance the understory by including shrubs and native grasses in public areas. A diverse understory provides additional food resources, as well as foraging and protective habitat for many native birds and mammal species. It is also important for deterring the Noisy Miner, a native pest bird species that will aggressively defend its territory and eliminate most other birds from an area (Lindenmayer et al. 2018).

Figure 3. Examples of habitat analogues for biodiversity in built environments. a) Purpose-built nest boxes in external wall of Gutman Visitor Centre, of the Jerusalem Bird Observatory, Israel. By Weinstein Vaadia Architects. Photo by Amir Balaban. b) Artistic installation featuring nesting structures for birds and anti-bird collision window film. By Joyce Hwang, Ellen Driscoll and Matthew Hume. Photo: http://www.expandedenvironment.org/joyce-hwang-bower/. c) Purpose-built external wall ledges for local insect and bird species on school building Building 18, Paris France. By Chartier Dalix Architects. Photo by Takuji Shimmura. d) Bat roosting structure, Bat Tower, in Griffis Sculpture Park, New York, United States of America. By Joyce Hwang. Photo: http://www.antsoftheprairie.com/?page_id=203. e) Bird nest box designed to be retrofitted to standard concrete block. By Snohetta. Photo by Snohetta. f) Blue tit bird using purpose-built nest hole in brick wall of building, The Bird Brick House in the United Kingdom. By Bird Brick Houses. Photo: http://www.birdbrickhouses.co.uk/brick-nesting-boxes/nesting-boxes/. g) Bee in purpose-built concrete bee brick, Bee Brick, in the United Kingdom. By Green and Blue. Photo: https://greenandblue.co.uk/product/bee-brick/

- Seek opportunities to incorporate analogue habitats into the built environment, including in the fabric of the built form (eg. nesting bricks, habitat boxes, biodiverse green walls and roofs; Figure 3). Species such as the blue-banded bee will utilize analogue habitats (mudbricks with specially drilled holes) for nesting under the right conditions (Box 1).

- Encourage residents to contribute to biodiversity by planting diverse gardens that provide food and habitat for native species. Private gardens are known to make a significant contribution to biodiversity in urban areas (Goddard et al. 2010) and can even contribute to improved connectivity and dispersal (Vergnes et al. 2012). Residents can be encouraged to contribute in this way by providing opportunities for residents to participate in wildlife gardening programs (Mumaw & Bekessy 2017) or by providing lists/recommendations about preferred garden plants through the local council and local nurseries. Working with builders and their preferred landscaping companies presents an additional opportunity to promote biodiversity enhancing private greenspaces.

4. Protect and enhance waterways and wetlands as a key focal opportunity for rewilding and community engagement

Enhancement of the on-site waterways and wetlands provides an exciting opportunity to attract the species of waterbirds which historically utilised the site, including Latham's snipe, Eastern great egret, Nankeen night heron, Lewin's rail and Royal spoonbill. In addition, there is scope to provide habitat for the nationally-threatened Growling grass frog in natural and man-made water bodies across the property. Migratory species, such as the Latham's snipe, are particularly notable for their community engagement potential.

BSUD to achieve this would include continuing to protect and enhance the vegetation along Jackson's Creek and in low-lying drainage areas and considering the ecological value of man-made water bodies, such as dams, which are currently onsite. In addition, it will be important to consider how any proposed development may alter the site's hydrology (with respect to both quality and quantity) in consultation with integrated water management specialists and ecologists.

5. Facilitate dispersal

BSUD aims to blur the boundaries between habitat and non-habitat and, in so doing, reduce barriers to dispersal. Nonetheless, urban and agricultural environments will remain inhospitable to some species. Recent research has shown that of the landscape-level factors that affect species richness in urban greenspaces, the provision of corridors between habitat patches is the single most important factor, significantly more effective than having a number of stepping stones amidst an urban environment (Beninde et al. 2015). This highlights the importance of BSUD for reconceptualising the built environment as habitat, and therefore the potential biodiversity benefits that may be realized if the built urban environment can begin to function as a connecting corridor in its own right. This is an exciting area for action research that presents real opportunities for novel contributions to sustainable urban development.

Dispersal and connectivity will, in most cases, be species-specific. By way of example, consider, the requirements of the following species, which are either present at Glen Junor or present real potential for rewilding:

Brown Treecreeper, *Climacteris picumnus victoriae* Photo by By Francesco Veronesi, reproduced under Creative Commons licence [CC BY-SA 2.0] via Wikimedia Commons.

The brown treecreeper, a representative of a vulnerable group of native bird species known collectively as woodland birds, will move between patches of suitable woodland habitat to forage and breed, provided that the distance between large patches is not more than 1.1km, and that this distance is connected by stepping stones of scattered trees not more than 100- 150m apart (Doerr et al. 2014).

Populations of the growling grass frog function as a meta-population, clusters of spatially-discrete populations connected by occasional dispersal. These frogs therefore need multiple wetlands and areas of suitable habitat to survive, and will disperse via waterways and wetter areas of land to move between wetlands. Dispersal is critical to the survival of this species in an area. Growling grass frogs will not disperse further than 200 – 300m between wetlands (DELWP 2017a).

Blue-banded bees or other insects may respond to very localized attempts to improve connectivity through street or backyard plantings (Box 1). Low-rise green roofs have been shown to provide habitat for diverse insect communities in other parts of the world (Brenneisen 2006), but current knowledge about the vertical distance different insects and pollinators will disperse is unknown, and there is a chance that green roofs on higher developments will be unable to deliver the same habitat and connectivity benefits.

Some general recommendations for facilitating dispersal at Glen Junor include:

- Minimise barriers to dispersal, including vertical barriers, during planning and design, paying particular attention to whether known occurrences of individual species or remnant patches of similar vegetation/ecosystems have been isolated from each other by elements of the built environment.
- Consider dispersal and connectivity at multiple scales and for multiple species; diverse approaches to improving connectivity will be required.
- Prioritise the retention or establishment of corridors where possible, to be augmented by stepping stones within inhospitable land uses.
- Where possible, draw on specific recommendations for individual species. For example, detailed guidelines about crossing design standards are available for the growling grass frog (DELWP 2017b).
- Consider the complementary roles of public and private space for enhancing connectivity (See Box 1).

Design to reconnect people with nature and enhance stewardship

A key objective of biodiversity sensitive urban design is to help establish a connection between the eventual residents and the natural environment in which they live. It is thought that this connection will be beneficial to residents, as well as the native species and ecosystems that are a feature of the site. There are numerous ways in which biodiversity stewardship might be enhanced or created in urban environments. These range from careful planning and urban design, to establishing 'cues to care', and place-based environmental education (Nassauer 1985; Marshall 2013; Eilam & Garrard 2017).

Native grassy ecosystems have historically suffered from poor public perception (Ives & Kendal 2013; Farrar 2016) . This may be due to a number of factors, including a lack of understanding about the ecosystem and the species it supports, a perception of grasslands as weedy and poorly managed and associated threats posed by fire and snakes, and - particularly in urban areas - the historical practice of excluding resident access to grassland conservation reserves. This poor public perception may be addressed through:

Interpretive signage at the Kayes Creek Grassland Reserve in Derrimut.
Photo: Georgia Garrard

- Urban design that demonstrates that native ecosystems are places of value and that, despite their arguably 'messy' appearance, they are cared for and managed. Such 'Cues to Care' include erecting interpretative signage at key sites of public access, and establishing a more orderly edge to native remnants (such as a managed buffer planted with some of the more engaging native plant species, like the native geraniums noted as likely being present at Glen Junor) in places where the ecosystems interface with the built environment (Marshall 2013).

- Providing the community with information about the management of native ecosystems from the very beginning of development and as key management actions occur.

- Promoting and resourcing, early on, the establishment of a 'Friends of' or other community group to encourage interaction, understanding, maintenance and long-term community support for the grassland (Marshall 2013). Early engagement with the existing community group within the established Eynesbury township presents an exciting opportunity in this regard.

- Encouraging curiosity about native ecosystems and facilitating public access to them in a way that protects ecological integrity. This can be achieved in a number of ways, including staged fencing, raised pathways, and fences that allow pedestrian but not vehicular access. An excellent and thorough set of urban design guidelines for protecting native grasslands whilst facilitating public access is found in Marshall (2013).

- Working with schools and local councils to set up place-based education programs in local conservation reserves. Such programs have been shown to foster a sense of care for native ecosystems in primary school students and their parents (Eilam & Garrard 2017).

A key challenge will be to link Glen Junor residents to the native ecosystems that are a feature of their regional landscape. We recommend the following for facilitating this:

- Incorporating well-managed native ecosystems within the urban matrix that are designed to encourage community access with minimal ecological impact (see above).

- Using interpretative signage in urban remnants to establish links with the ecology and management of the broader regional landscape. This would include links to actions and practices included in conservation and farm management plans.

- Using local species in public landscaping to facilitate engagement with these systems everyday, where people live, work and play. This could include landscaping in nature strips and road plantings, urban greenspaces, roundabouts,

schools, hospitals, commercial areas, public transport stops etc. As above, encouraging residents to include local species in private spaces, engaging with residential landscaping contractors and promoting wildlife gardening may help to facilitate greater connection between private space and the surrounding environmental context.

- Consider establishing a totem or iconic species program that links individual target species to particular neighbourhoods. There is significant scope here to engage with local Indigenous communities and Traditional Owners.

Promoting biodiversity stewardship through biodiversity sensitive urban design will be enhanced by considering the nature of the urban form (Box 2). In particular, for encouraging stewardship, we recommend:

- Prioritising low- and medium-rise residential buildings that enable visual connection to nature on the ground level and, when designed to be overlooking semi-private courtyards, are thought to be most effective at promoting a sense of stewardship over shared spaces (Dias De Carvalho, 2015).

- Alongside incorporating native plantings into public spaces, activating streetscapes to encourage people to have incidental, everyday experiences with nature, in the places where they live, work, and play.

Box 2. The relationship between BSUD, every day nature and urban form

The biodiversity and social benefits of BSUD are intimately linked to urban form, and some urban forms are more compatible with BSUD than others. The enormous footprint of low density, detached housing is driving excessive clearing of some of Australia's most endangered ecosystems, including Melbourne's native temperate grasslands, the Cumberland Plains Woodlands on the outskirts of Sydney and Perth's coastal heath. Furthermore, this housing typology, with only limited view over public space, does not promote public engagement or stewardship. Similarly, high-rise apartment living does little to promote connection to the natural or social realm and, aside from extreme design responses, such as trees perched precariously on the sides of 60-storey buildings, high-rise has little capacity to incorporate nature in a meaningful way.

Conversely, mid-rise development is well suited for, and may even enhance, BSUD. Facades of 4-6 storeys are appropriate for biodiverse green walls and roofs, and even at the highest levels, residents can maintain a connection to the natural world (Fig B2.1).

When combined with internal courtyards, mid-rise urban forms can provide semi-private green spaces capable of supporting living systems within the built fabric, whilst also helping to foster a sense of nature stewardship in residents (Dias De Carvalho, 2015; Garrard et al. 2015).

Figure B2.1. Development cross-section demonstrating how residents can maintain connection to the natural world in mid-rise development. This connection is broken above 5 storeys. Image: Simon van Wijnen.

Finally, urban form can alter perceptions of the interface between the human and natural realms. A recent collaboration between ecologists and architects led to a reimagining of outer urban development in Melbourne in which raised, modular apartments were used to reconceptualise the 'risks' associated with wildfire in fire-prone landscapes (Fig B2.2; Garrard et al. 2016).

Figure B2.2. Connecting people to nature in fire-prone landscapes. Image: Mauro Baracco, Jonathan Ware, Catherine Horwill, RMIT School of Architecture & Design.

Interconnection with other key planning areas

The success of biodiversity sensitive urban design hinges in part on its alignment and integration with other key planning areas. Without adequately considering how BSUD integrates with other elements of planning and design, actions are unlikely to succeed, and the potential for synergistic social, environmental and economic benefits is unlikely to be fully realised. Key areas requiring integration with BSUD include:

Design & Masterplanning

Design and masterplanning will be critical for delivering desired spatial arrangement of habitat (for example to facilitate dispersal), for fostering stewardship, and for ensuring that residents have access to everyday nature (Box 2).

Biodiversity Management

Minimum biodiversity management requirements are established in various legal and policy instruments. BSUD can enhance outcomes for these species through careful and innovative urban design.

Farm Management

Careful farm management can help contribute to the conservation of biodiversity, for example through biomass reduction in native grasslands. Furthermore, BSUD has the potential to help manage the interface between the 'urban' and 'rural' environments and management.

Social Planning

BSUD enhances connection to nature, which is associated with a wide range of community and human health and wellbeing benefits. BSUD also has the potential to enhance the productivity and activity of business/retail districts.

Integrated Water Management

BSUD has synergies with water senstive urban design; vegetation can be used to reduce run-off and nutrient loads through vegetated swales and rain gardens, and water/drainage issues can be managed to promote biodiversity.

Statutory Planning

The successful implementation of BSUD will rely on integration with key statutory planning instruments including consideration of land use zones, DPOs, DDOs and Section 173 Agreements (to guide the character and development of the neighbourhood).

Conclusions

Given the existence of ecologically-signficant species and ecosystems, the location of the site in within a region of high ecological value and the history of weed invasion and land degradation, it is our recommendation that development at Glen Junor should go above and beyond what is currently required by Victorian and Federal legislation. Glen Junor has great potential as a demonstration site for re-imagining development in Australia's urban fringe environments. Given that these environments are home to so many of Australia's threatened species and ecosystems, there is a lot to lose - if the status quo continues, greenfield development will almost certainly lead to the extinction of species and potentially whole ecosystems. Yet, this also means that there is a lot to be gained - reconceptualising biodiversity as an asset to be maximised, rather than a problem or a constraint to be dealt with could have enormous positive repercussions. Embedding nature in the urban matrix has the potential to mitigate numerous liveability challenges confronting Australian cities, enhancing health and well-being, building resilience in the face of climate change and creating unique, thriving streetscapes.

Delivering BSUD in Glen Junor will provide much-needed opportunities for action-research to resolve outstanding questions. For example, how can urban vegetation be spatially arranged in cities to maximize daily interactions with nature and the diversity of species that can utilize it? What type of vegetation is best in urban settings for temperature regulation, psychological restoration or stormwater treatment? Can we develop nature-based solutions for planning conflicts? Application of biodiversity sensitive urban design principles in Glen Junor will play an important role in developing an evidence base for the ecological, social and economic outcomes that are possible in greenfield development designed with nature as a key priority.

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