METROTUNNEL

LIVING INFRASTRUCTURE PLAN

A Collaborative Partnership:

MELBOURNE METRO RAIL AUTHORITY

LOCI ENVIRONMENT & PLACE

VICTORIA State Government

THE METRO TUNNEL WILL DEMONSTRATE WORLD LEADING EXCELLENCE TO CREATE A LIVING INFRASTRUCTURE LEGACY FOR A MORE LIVEABLE VICTORIA.

Loci Environment & Place Inc. draws upon a suite of provider partners to deliver specialist advice for each of its projects. This Living Infrastructure Plan was developed in partnership with Urban Forest Consulting, E2Designlab, SESL Australia, and Royal Botanic Gardens Australia – Australian Research Centre for Urban Ecology.

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EXECUTIVE SUMMARY

CITIES AND NATURE

Our cities today continue to face new challenges in their quest to accommodate rapid population growth in a time of climate change and resource constraints.

Over recent years, urban practitioners and researchers from multiple fields of expertise have been coming together in different ways to develop new approaches for planning and building cities that will enhance urban resilience. It is fast emerging that one of the key things we need to approach differently to achieve multiple environmental, social and economic benefits is incorporate more nature into our built environment and everyday lives.

With this in mind, it was determined that the Metro Tunnel Project could provide a great example and legacy for Melbourne and beyond by developing a Living Infrastructure Plan to integrate more nature into its design.

For this plan, 'nature' refers to our 'green infrastructure' including trees, gardens, green walls and roofs, and open spaces, and the 'blue infrastructure' of our water bodies including bays, lakes, wetlands and waterways. We are collectively referring to this as 'living infrastructure' to support all of the interconnected ecosystems within an urban catchment. This includes the rivers, creeks, hills, valleys, soils, rainfall and climate present in the system and the species of plants, animals, microorganisms and other biodiversity.

COLLABORATING FOR LIVING INFRASTRUCTURE

The Metro Tunnel will introduce two nine-kilometre rail tunnels from Kensington to South Yarra, tunnelling underneath Swanston Street with five new underground stations at Arden, Parkville, CBD North, CBD South and Domain. This investment will provide the foundation for expanding Melbourne's public transport network helping to ensure Melbourne remains one of the world's most liveable cities[1] now and into the future.

Leading living infrastructure outcomes can be delivered via the Metro Tunnel Project by drawing on the support and knowledge of its local government partners; City of Melbourne, City of Port Phillip and City of Stonnington. Inner Melbourne is already recognised internationally for its progressive city planning[2] that responds to climate change.

Melbourne Metro Rail Authority seeks to contribute to this local leadership by providing for strong living infrastructure measures, and welcomes the support, knowledge and collaboration opportunities with local government, industry bodies and research organisations to garner more environmental, community and learning legacies that will benefit all of Victoria. A partnership agreement with non-profit organisation Loci Environment & Place Inc. to develop the plan has enabled the recommendations to be drafted specifically for the broader benefit of urban sustainability outcomes in Melbourne.

Melbourne Metro Rail Authority welcomes further partnerships to pursue the living infrastructure opportunities set out in this plan.

1 http://www.economist.com/blogs/graphicdetail/2015/08/daily-chart-5.
2 http://www.thefifthestate.com.au/events/awards-event-news/city-of-melbourne-wins-world-climate-adaptation-award/67942.

METRO TUNNEL'S LIVING INFRASTRUCTURE PLAN

The Living Infrastructure Plan for the Metro Tunnel sets out design, implementation and applied learning solutions to help ensure the project results in healthy, resilient and biodiverse green urban landscapes to support the future liveability of Melbourne. This means:

+ creating 'greener than before' landscapes in inner Melbourne to support environmental, public health and wellbeing outcomes; and
+ expanding urban planning and development practitioner knowledge that will in turn support greater sustainable development and climate resilience in our cities.

This Living Infrastructure Plan considers ecosystem dynamics alongside landscape aesthetic. It sets out key strategies to address urban ecosystems including biodiversity, soil health, canopy planning, and water management to help protect our wider environment along with public health and wellbeing.

The plan sets out existing conditions, guiding principles, practice notes and action measures to support the delivery of living infrastructure targets including doubling tree canopy cover by 2040, best practice stormwater management and 25% vegetation coverage for all open space areas.

The development of the Living Infrastructure Plan actively supports the Metro Tunnel's Environmental Management Framework, Environmental Performance Requirements, Sustainability Targets and Urban Design Framework.

1. INTRODUCTION

A SHARED CHALLENGE

Our cities today continue to face new challenges in their quest to accommodate rapid population growth in a time of climate change and resource constraints[3]. To be sustainable, cities need to be resilient. They need to recover from disturbance without losing their ability to be sustainable over the longer term[4].

Over recent years, urban practitioners from multiple fields have been coming together in many different ways[5] to develop new knowledge and approaches that change the way we plan and build cities to increase our long term resilience. Melbourne Metro Rail Authority is supporting this challenge through its commitments outlined in the Metro Tunnel Sustainability Targets.

In Melbourne, we have seen these collaborations via regional initiatives (such as the Inner Melbourne Action Plan), via national initiatives (such as the Clean Air & Urban Landscapes Hub), and via international initiatives (such as 100 Resilient Cities). Industry collaborations are also important in taking on these challenges as they are able to connect with the practitioners and providers that greatly influence the shape of the city. This is seen by the ongoing success of the 202020Vision initiative of Horticulture Innovation Australia and the recent emergence of non-profit organisation, Loci Environment and Place Inc.

From such collaborations we have collectively learned that one central way our cities can increase their social, economic and environmental resilience is to incorporate more nature.

SUPPORTING LOCAL LEADERSHIP

Inner Melbourne is already recognised internationally for its progressive city planning[6] that responds to climate change. This is seen in many ways including the urban forest, urban ecology and water sensitive cities innovations that have been applied by the City of Melbourne, City of Port Phillip and City of Stonnington. This has quite often been achieved in partnership with leading research organisations including the CRC for Water Sensitive Cities, the Australian Research Centre for Urban Ecology, and the National Environmental Science Programme's Clean Air and Urban Landscapes Hub.

It was the recognition of the need for more collaboration among practitioners from different urban disciplines that saw the emergence of non-profit organisation Loci Environment & Place Inc. Loci are the lead collaborator with Melbourne Metro Rail Authority (MMRA) in developing this Living Infrastructure Plan.

MMRA seeks to contribute to this local leadership by providing strong living infrastructure measures. Continued support, knowledge and collaboration with local government and research organisations is welcomed as an effective way to garner more environmental, community and learning legacies that will benefit all of Victoria.

Whilst we draw on experts and researchers for our plans, we also know that indigenous knowledge, community knowledge and local stewardship is of equal importance in helping us deliver actions to enhance and protect our nature in the city. This ranges from active community groups through to the partnership with urban sustainability practitioners Loci Environment & Place Inc.

3 https://www.theguardian.com/artanddesign/2010/mar/29/urban-age-cities-design.
4 Ahern J (2013) Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology* 28: 1203-1212.
5 http://www.iwa-network.org/transdisciplinary-teams-the-future-of-strategic-urban-planning/.
6 http://www.thefifthestate.com.au/events/awards-event-news/city-of-melbourne-wins-world-climate-adaptation-award/67942.

BRINGING TOGETHER OUR BUILT AND LIVING INFRASTRUCTURE

When completed, the Metro Tunnel will provide new world class public transport infrastructure and will create a landscape that contributes positively to the environment. By matching the built infrastructure legacy of the Metro Tunnel with a living infrastructure legacy, this project will contribute to our city and its community to be resilient and adaptable in dealing with ongoing changes in climate, urban development and population growth.

Metro Tunnel provides an opportunity to enhance our urban landscapes so they are more resilient to climate change. New plantings will need to consider future extended droughts, increased frequency and duration of heat waves, and damage caused by severe storms and heavy rainfall[7]. Trees planted by the project have the potential to be contributing to the liveability of the city in 2100 provided they have appropriate growing conditions and are suitable species.

The Metro Tunnel's program for living infrastructure brings together measures for urban ecosystems, urban forests, urban soils, and urban water based on the best available knowledge.

It acts to ensure that these living elements of our cities are integrated within our built infrastructure[8] and designed around the ongoing needs of healthy communities.

7 Fünfgeld, H. and D. McEvoy (2011). Framing Climate Change Adaptation in Policy and Practice. VCCCAR Project: Framing Adaptation in the Victorian Context. Working Paper 1, April 2011. VCCCAR.
8 http://www.sustainablecitiescollective.com/deeproot/1157511/urban-forest-asset-class.

2. HOW TO USE THIS PLAN

This Living Infrastructure Plan has been developed to inform and aid design and construction teams in meeting the objectives of the Metro Tunnel Project with regard to its sustainability targets, in particular the Urban Ecology and Vegetation Targets and the Water Targets.

It contains seven key sections; the contents and purpose of each are described in the table below.

The Living Infrastructure Plan is a 'whole of project' plan that will be delivered through the Metro Tunnel work packages and partnerships. The Plan will be supported by technical guidance notes and the Metro Tunnel Project environmental performance requirements.

The Living Infrastructure Plan includes a range of specialist terms. Definitions are provided in the glossary.

Table 1: Contents of the Living Infrastructure Plan and their purpose

Living Infrastructure Plan Section	Purpose
Vision	The Vision outlines the overall purpose of the plan and the vision for living infrastructure arising from the Metro Tunnel Project.
Targets	The targets section outlines the Living Infrastructure Targets that are to be achieved by the Metro Tunnel. These targets are also listed in Metro Tunnel sustainability targets and are complementary to some of the Environment Effects Statement Environmental Performance Requirements.
Existing Living Infrastructure	This section provides an analysis of the existing urban context, particularly in the proposed construction areas for Metro Tunnel Project.
Strategies	The strategies section outlines measures and opportunities that are to be applied to the design and construction of the Metro Tunnel. Strategies are provided to enhance ecosystems, soil, and water.
Engagement and Knowledge Sharing	The engagement and knowledge sharing section also incorporates monitoring opportunities to support community and practitioner connections and benefits.
Best Practice Notes	The Best Practice Notes section provides guidance on key design and construction elements that will be applied under the Living Infrastructure Plan.
Glossary	The glossary has been developed to assist partners and delivery agents to understand the context of concepts that can have different meanings in different contexts.

3. VISION

The Metro Tunnel will demonstrate world leading excellence to create a living infrastructure legacy for a more liveable Victoria.

Through application of the Living Infrastructure Plan, the Metro Tunnel will create urban landscapes that:

+ are more biodiverse, healthy and climate change resilient;
+ successfully provide ecosystem services which improve the urban environment;
+ add amenity and enhance local character;
+ support liveable, active, healthy and connected communities; and
+ provide inspiration, opportunities and case studies to support increased uptake of living infrastructure initiatives in future urban planning, design, engagement and management.

4. SUSTAINABILITY TARGETS

METRO TUNNEL PROJECT WIDE SUSTAINABILITY TARGETS

'Metro Tunnel is committed to connecting commuters in the healthiest, most sustainable way possible, helping to ensure that Melbourne remains the most liveable city in the world and leaving a lasting sustainable legacy for present and future generations – environmentally, socially and economically.

Metro Tunnel Project partners will meet a number of targets across key themes throughout the Project lifecycle. These targets, which will be applied uniquely to each work package, will enable the delivery of high quality sustainability outcomes in a complex project environment.'

The Living Infrastructure Plan sets out measures to support all Sustainability Targets (as outlined in Appendix B) with a primary emphasis on Urban Ecology and Vegetation targets and Water targets.

Urban Ecology Targets

- Double tree canopy cover by 2040 compared to base case through the reinstatement of lost trees, planting of new trees, and the creation of improved growing conditions.
- Total amount of vegetated surface permanently gained post construction must be greater than total amount of vegetated surface area permanently lost.
- At least 25% of new and reinstated planting areas must consist of diverse, multi-storey plantings for biodiversity.

Water Targets

- Manage stormwater runoff from new or reinstated ground surfaces and roof areas to achieve the best practice water quality performance objectives as set out in the Urban Stormwater Best Practice Environmental Management Guidelines (Victoria).
- Use rainwater and/or stormwater to provide passive irrigation to all tree plots and vegetated areas to support soil moisture needs.

The targets support the following policy commitments of the Victorian Government including the *Climate Change Adaptation Plan*, *Plan Melbourne 2017-2050*, *Water for Victoria Discussion Paper*, and *Biodiversity 2037*.

The targets support the Metro Tunnel Project's Environmental Performance Requirements as shown in Appendix A and Sustainability Targets as shown in Appendix B.

Delivery of these targets will be driven by measures set out in Section 8 of this Plan.

Metro Tunnel targets seek to best respond to the policy commitments of our collaborative partners including:

+ City of Melbourne's *Open Space Strategy 2012*, *Urban Forest Strategy 2014*, *Future Urban Forest Report 2016*, *Draft Urban Ecology and Biodiversity Strategy 2016*, *Total Watermark 2014*, *Bicycle Plan 2016.*
+ City of Port Phillip's *Open Space Strategy 2009*, *Greening Port Phillip 2010*, *Water Management Plan*, *Climate Adaptation Plan 2010*, *Bike Plan 2010.*
+ City of Stonnington's *Open Space Strategies 2013*, *Public Realm Strategy 2010*, *Sustainable Environment Strategy 2013, Draft Urban Forest Strategy.*
+ Regional Planning *Resilient Melbourne Strategy*, *Draft Inner Melbourne Action Plan*, *Greening the West Strategy.*

5. WHAT IS 'LIVING INFRASTRUCTURE'?

Urban environments have only recently begun to be viewed as important ecological systems with the ability to support a wide range of plants, animals, fungi, invertebrates and micro-organisms, as well as natural processes such nutrient cycling, water filtration, air purification and carbon sequestration.

Living infrastructure refers to all of the interconnected ecosystems within an urban catchment. This includes the rivers, creeks, hills, valleys, soils, rainfall and climate present in the system, and the species of plants, animals, microorganisms and other biodiversity.

Living infrastructure builds upon and combines the concepts of 'green infrastructure' (which focuses on vegetation) and 'blue infrastructure' (which focuses on water management) in urban landscapes.

Living infrastructure includes parks, garden beds, lawn, trees, green roofs/ walls, swales, raingardens, wetlands, lakes, waterways, bays and more.

Throughout these examples, living infrastructure applies a common approach of working with nature to handle more complexities than traditional planning[9]. This in turn means that cities can move beyond their traditional role of drawing from the environment to instead helping to restore it and leaving it in a better condition than it was before[10].

Some of the critical design features[11] that help define living infrastructure include:

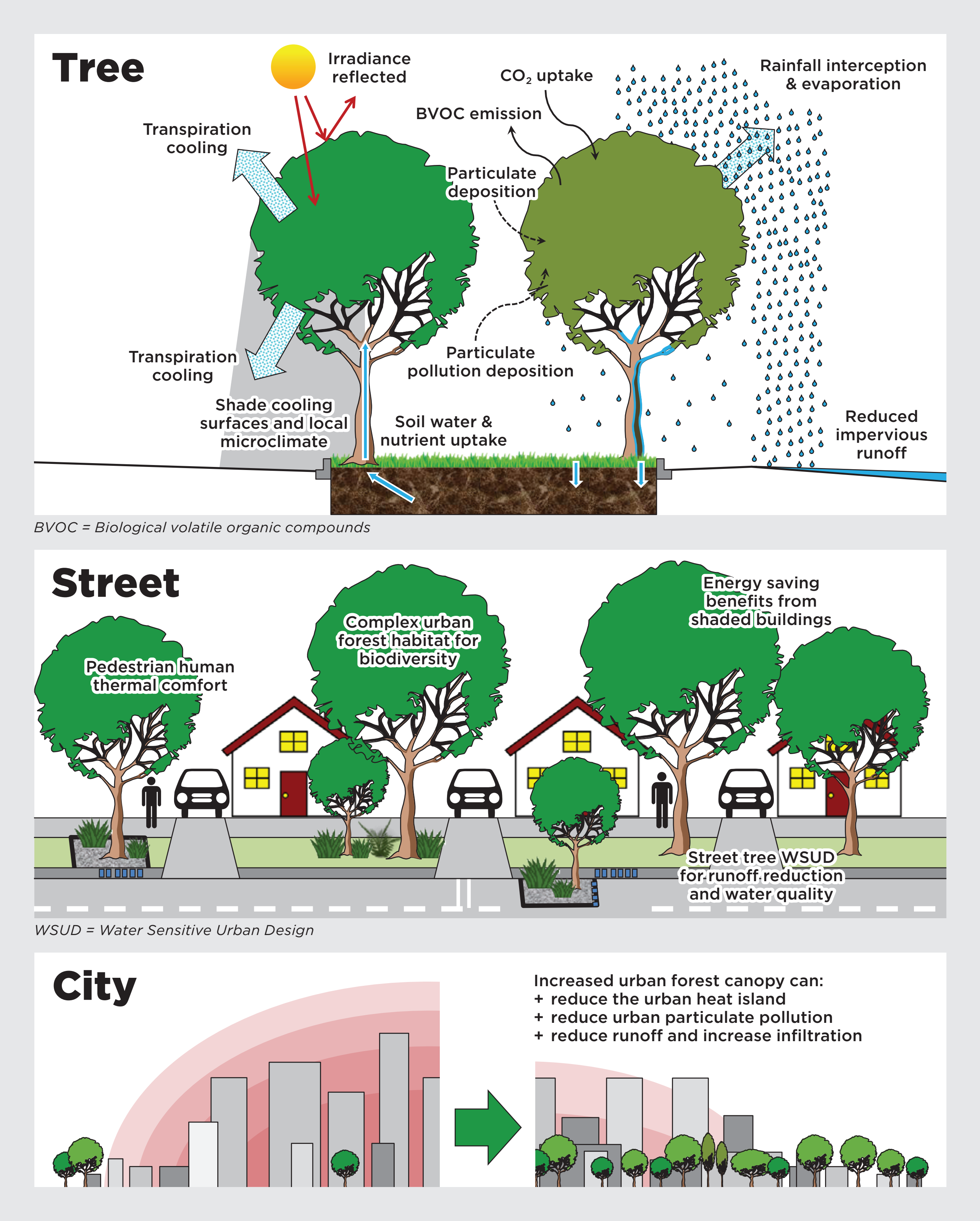
+ **Being multi-scale:** finding ways for a single site to contribute to living infrastructure benefits at precinct, community and regional scale;
+ **Being integrated:** linking with the existing built and social infrastructure that already exists;
+ **Being multi-functional:** providing multiple urban benefits from one design to make the best use of urban land; and
+ **Being connected:** linking different green and blue spaces together in addition to linking our community.

Useful guides and sustainability rating tools are emerging to provide a framework to measure urban design outcomes that can support living infrastructure objectives and these are referred to throughout the Living Infrastructure Plan.

It is important to remember that living infrastructure is dependent on community acceptance and stewardship[12]. Community groups, nonprofits and local government can drive or enable community initiatives and connections that green our cities. In return, we are all rewarded with local precincts sharing benefits of increased retail trade, reduced crime and improved physical and mental health that is all evidenced in more vegetated urban areas.

9 Hansen R and Pauleit S (2014) From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *Ambio* 43: 516-529.
10 Standish RJ, Hobb RJ (2012) Improving city life: options for ecological restoration in urban landscapes and how these might influence interactions between people and nature. *Landscape Ecol* 28 1213-1221.
11 Hansen R and Pauleit S (2014) From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *Ambio* 43: 516-529.
12 Goddard MA, Dougill AJ, Benton TG (2009) Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology and Evolution* Vol 25 No 2 90-98.

Figure 1: Living infrastructure ecosystem services provided by the urban forest at different scales[13]



13 Livesley, S. J.; McPherson, E. G.; Calfapietra, C. (2016) The Urban Forest and Ecosystem Services: Impacts on Urban Water, Heat, and Pollution Cycles at the Tree, Street, and City Scale. *Journal of Environmental Quality*. 45:1. 119-124.

The ecosystem service[14] benefits of planning for healthy living infrastructure in our cities include:

Resilience

+ increasing resilience of vegetation, soils, and water bodies to more extreme **climate variations** including extended periods of drought, more extreme storms and extended heatwaves[15]
+ increasing soil and biomass **carbon sequestration** to reduce urban contribution to greenhouse gases[16]
+ reducing the pressure on **local drainage systems and reduce the risk of flooding** through water sensitive urban design and soil enhancement[17]
+ improving the management, maintenance and valuation practices of **urban infrastructure**[18]
+ improving the **connections between people and their local place** which in turn helps them care for nature in their neighbourhood[19].

Biodiversity

+ supporting **species richness** by increasing habitat quantity and quality in urbanised areas[20]
+ improving the **health of waterways and bays**[21] by constructing landscapes, soils and vegetation to filter, treat and reduce the flow of stormwater.

Health

+ increasing mental[22] and physical[23] wellbeing benefits of people by increasing their **connection to urban nature**
+ reducing **urban heat impacts of vulnerable people**[24] by providing urban trees and vegetation with the nutrients, moisture, space and structural stability necessary for healthy growth and maximum canopy
+ supporting greater **pollution reduction, prevention and remediation** measures for soils and groundwater to maximise community health and wellbeing, environmental and resource protection[25].

Self Sustainability

+ **increasing recycling of minerals and nutrients** within urban ecosystems to sustain natural resources[26]
+ **harnessing rainwater and stormwater** as a resource for new and reinstated landscapes[27].

Innovation

+ optimising benefits for people, places and ecosystems through **research collaborations**
+ providing **leadership, legacy, and knowledge growth** in the implementation of sustainable urban development.

14 Elmqvist T, Setala H, Handel SN, van der Ploeg S, Aronson J, Blignaut JN, Gomez-Baggethun E, Nowak DJ, Kronenberg J and de Groot R (2015) Benefits of restoring ecosystem services in urban areas *Science Direct* 14 101-108.
15 Ahern J (2013) Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology* 28: 1203-1212.
16 Dorendorf J, Eschenbach A, Schmidt K, JEnsen K (2015) Both tree and soil carbon need to be quantified for carbon assessments of cities. *Urban Forestry & Urban Greening*. 14, 3, 447-455.
17 https://www.clearwater.asn.au/resource-library/publications-and-reports/mainstreaming-flood-resilience-in-cities.php.
18 https://www.vu.edu.au/sites/default/files/cses/pdfs/green-infrastructure-economic-framework-fin-r.pdf.
19 Chapin, F.S.III, et al., 2012. Design principles for social-ecological transformation toward sustainability: lessons from New Zealand sense of place. Ecosphere, art40, 3 (5), 1–22.
20 http://www.thenatureofcities.com/2014/04/14/four-ways-to-reduce-the-loss-of-native-plants-and-animals-from-our-cities-and-towns/.
21 https://www.clearwater.asn.au/user-data/resource-files/2016_08-waterways-issues-paper-pub.pdf.
22 https://www.theguardian.com/sustainable-business/2016/aug/17/urban-planners-improve-mental-health-cities?CMP=share_btn_tw.
23 https://www.be.unsw.edu.au/sites/default/files/upload/pdf/cf/hbep/publications/attachments/4HBEPLiteraturereview-ExecutiveSummary.pdf.
24 Coutts, AM.; Tapper, NJ.; Beringer, J; Loughnan, M; Demuzere, M. (2013) The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context *Progress in Physical Geography*. Feb 2013, Vol. 37 Issue 1, p2-28.
25 Elmqvist T, Setala H, Handel SN, van der Ploeg S, Aronson J, Blignaut JN, Gomez-Baggethun E, Nowak DJ, Kronenberg J and de Groot R (2015) Benefits of restoring ecosystem services in urban areas *Science Direct* 14 101-108.
26 Templer P, Toll J, Hutyra L, Raciti S (2015) Nitrogen and carbon export from urban areas through removal and export of litterfall. *Environmental Pollution* 197 256-261.
27 Fletcher, T. D., Deletic, A., Mitchell, V. G., & Hatt, B. E. (2008). Reuse of urban runoff in Australia: a review of recent advances and remaining challenges. *Journal of Environmental Quality*, 37(5_Supplement), S-11.

6. WHY IS A LIVING INFRASTRUCTURE PLAN NEEDED FOR THE METRO TUNNEL PROJECT?

A Living Infrastructure Plan enables the project to expand its community legacy by creating landscaping solutions that connect well with current and future community needs.

It is also acknowledged that some necessary loss of trees during the construction of Metro Tunnel is a negative impact of a project that otherwise delivers great public benefits.

The Living Infrastructure Plan complements the Environmental Performance Requirements set out in the Environment Effects Statement (EES) that will ensure potential environmental, social, and economic impacts are avoided or mitigated. The Plan also enables opportunities to be taken that will support the implementation of Sustainability Targets and the Urban Design Framework.

We have learned from past projects and experience that the community's connection to trees needs to be fully recognised and supported. For the Metro Tunnel Project, the primary measures taken to address this include:

a) finding design solutions to minimise impacts on trees and making this process clear for the community (via the EPRs);

b) ensuring that the replacement landscape provides a healthy increase in canopy, and

c) improving long term urban landscape values by applying world leading planting standards for climate resilience.

The Living Infrastructure Plan incorporates the above measures within its broader environmental and liveability goals.

Figure 2: The *Living Infrastructure Plan* provides guidance that will help support the Metro Tunnel's Sustainability Targets and the Environmental Management Framework required under the Environment Effects Statement

The Metro Tunnel Project **Environment Effects Statement (EES)** released in May 2016 provided technical analysis to understand the impacts of the project whilst also setting out measures to reduce and protect against negative impacts that can arise.

The Metro Tunnel project will be delivered under an **Environmental Management Framework** as defined in the EES, including the need to meet Environmental Performance Requirements and Sustainability Targets.

The **Environment Performance Requirements (EPRs)** supported by this Living Infrastructure Plan are set out in Appendix A.

The **Sustainability Policy and Sustainability Targets** supported by this *Living Infrastructure Plan* are set out in Appendix B.

7. EXISTING LIVING INFRASTRUCTURE

The existing living infrastructure found along the Metro Tunnel alignment varies from suburb to suburb. Capturing the existing conditions enables a better understanding of opportunities to support living infrastructure outcomes.

The table below shows how the existing conditions link to the strategies set out in Section 8 of the Living Infrastructure Plan.

Table 2: Summary of existing condition information

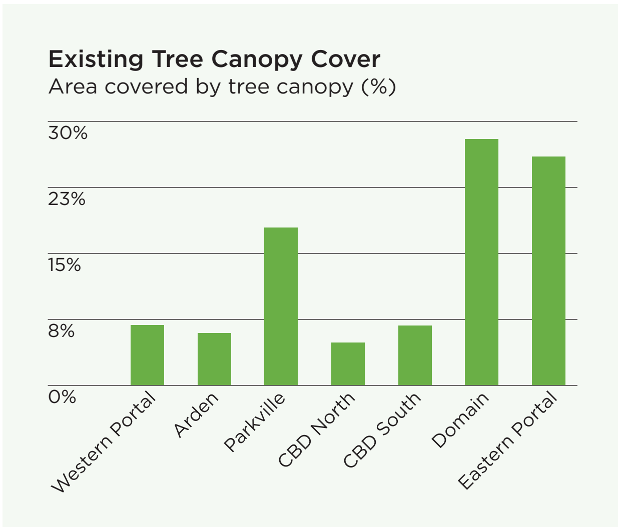
Living Infrastructure Strategy (see Section 8)	Existing Conditions Information
Urban Ecosystems	Tree Canopy Cover
	Open Space
	Urban Heat Island
	Biodiversity of Plants and Animals
Urban Soils	Urban Soils (overview)
Urban Water	Stormwater Quality
	Groundwater (overview)

7.1 TREE CANOPY COVER

Tree cover varies greatly for inner Melbourne and we can see in Figure 3 below that the lowest coverage is in the CBD and western portion of the tunnel surrounds.

The construction of Metro Tunnel will result in the removal of up to 900 trees. Given the exact number and locations of trees to be removed is unknown until final tunnel design is approved, the base canopy cover cannot be calculated. Until this information is confirmed, the following tree data is available as context.

Figure 3: Comparison of tree canopy cover for areas along the Metro Tunnel alignment



The inner urban precincts at CBD North and South along with Western Portal and Arden localities have very low existing tree coverage with an average of 6.25%. The tree coverage is four times greater at Domain and Eastern Portal with an average of 27% tree canopy within the precinct area. The alignment above the tunnel has a very high canopy cover as it runs underneath significant parkland and boulevards such as Fawkner Park, Kings Domain, St Kilda Rd and the leafiest streets of North Melbourne such as O'Shannassy Street.

Some of the existing urban forest, particularly within some project areas such as Domain and Parkville was planted over 100 years ago, and like many cities, it is important for urban forest managers to prepare succession plans for when these trees die. The City of Melbourne has been a leader in this succession planning, with its *Urban Forest Strategy*[28] and associated Precinct Plans[29] identifying renewal programs for individual trees to ensure the succession of healthy tree canopy cover. Replacement trees are ideally planted to minimise disruptions to the existing landscape, yet continue to provide streetscape amenity particularly along boulevards and avenues. The City of Port Phillip and City of Stonnington also support progressive urban forest management.

The increased emphasis in recent years of planting vegetation in urban spaces to best practice measures will help avoid the problems of previous decades where some trees in Melbourne were planted in less than ideal conditions. Poor soils, with limited root growing space and limited access to nutrients and water has prevented some trees from thriving and therefore limited their potential to provide maximum benefits. Space constrained conditions for tree growth in urban environments, as well as poor species selection, has also had impacts on urban infrastructure, resulting in pavement uplift and competition for space between underground utilities and tree roots searching for water and nutrients.

This Living Infrastructure Plan informs the design and construction of the Metro Tunnel Project to firstly limit the loss of existing tree canopy cover and secondly to ensure that replacement landscapes can support larger, healthier and longer lived tree canopies.

LINK TO SUSTAINABILITY TARGETS

Melbourne Metro Rail Authority is committed to the following Sustainability Target:

Double tree canopy cover by 2040 compared to base case through the reinstatement of lost trees, planting of new trees, and the creation of improved growing conditions.

The base case canopy cover (measured in square metres) can be calculated once the final project plans are delivered and the exact tree removal numbers and locations are known and approved. The canopy cover of removed trees will be calculated by Melbourne Metro Rail Authority to determine the extent of canopy loss using up to date aerial imagery in a desktop GIS study.

Achievement of the projected 2040 tree canopy target will be determined by modelling growth of the Metro Tunnel Project trees. The model will reflect initiatives such as soil structure and quality, root growing space and passive irrigation and use of advanced tree stock.

7.2 OPEN SPACE

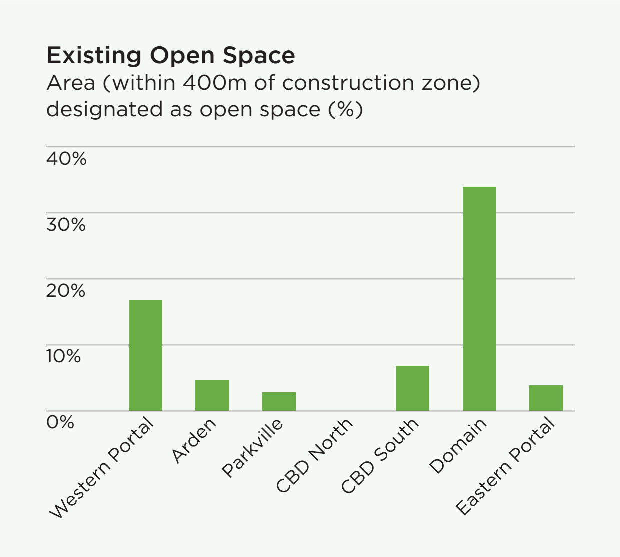
Open space refers to land that is reserved and accessible for public use. Public open space is defined as 'land in public ownership and/or under public management that provides recreation and leisure benefits'. This definition aligns with the State of Victoria's Planning Practice Note 70 Open Space Strategy[30].

Open space availability varies greatly for inner Melbourne and this variation is seen in the surrounds of Metro Tunnel.

Whilst the construction of Metro Tunnel will not result in the long term loss of any open space, it is valuable to understand existing open space patterns as they give context to the wider living infrastructure strategy. It is in this context that the following open space data has been compiled.

28 City of Melbourne, 2012. *Urban Forest Strategy* http://www.melbourne.vic.gov.au/community/parks-open-spaces/urban-forest/Pages/urban-forest-strategy.aspx.
29 City of Melbourne, 2014 *Urban Forest Precinct Plans* http://www.melbourne.vic.gov.au/community/parks-open-spaces/urban-forest/Pages/urban-forest-precinct-plans.aspx.
30 https://www.planning.vic.gov.au/policy-and-strategy/open-space-planning.

Figure 4: Existing open space around the Metro Tunnel Project construction areas



Most of the areas with the within walking distance (400 m) of the Metro Tunnel construction areas are low in open space with the Domain and Western Portal being the two areas of exception.

When aligning these existing open space conditions with the existing tree coverage in surrounding streets, the impacts for people and fauna will be most noticeable for CBD North, CBD South and Arden Street.

LINK TO SUSTAINABILITY TARGETS

This open space analysis has been included for reference information as there is no open space quantity target for the Metro Tunnel.

Figure 5: Map identifying local open spaces (in dark green) within 400m walking distance of the Metro Tunnel Project construction zones. Precincts with much lower availability of nearby open space are found in the CBD, North Melbourne and Kensington

7.3 URBAN HEAT ISLAND

The urban heat island effect is the result of hard impervious surfaces storing radiant heat during the day and re-radiating it out at night time[31]. This explains why in the height of summer, the air temperature at night is hotter in the City than in the surrounding suburbs and peri-urban areas.

The Metro Tunnel Project area covers parts of the City that are characterised by dense urban development with a high percentage of impervious surfaces resulting in some of the hottest parts of Melbourne.

Thermal hotspots, which are areas of excessive heat retention, are interspersed across all of the precincts, with the largest hotspot at CBD South.

Thermal imaging from the cities of Melbourne, Port Phillip and Stonnington identifies the following hotspots near Metro Tunnel Project construction areas:

Table 4: Localised hotspots identified by aerial thermal imagery (shown in Figure 6)

Precinct	Hotspots
Western Portal	Childers Street
Arden	Arden and Laurens Streets
Parkville	Grattan Street
CBD North	Lonsdale Street and Swanston Street
CBD South	Intersection of Flinders Street, Federation Square and Princes Bridge
Domain	Albert Road
Eastern Portal	Toorak and Chapel Streets
Tunnel network	Intersection of O'Shannassy and Harcourt Streets North Melbourne, Pelham Street Carlton, Linlithgow Ave onto St Kilda Rd and Toorak Road

31 Coutts A, Beringer J, and Tapper N (2010) Changing urban climate and CO_2 emissions: Implications for the development of policies for sustainable cities. Urban Policy and Research 28(1): 27-47.

Figure 6: The urban heat island effect in Melbourne (VCCCAR 2013)[32]

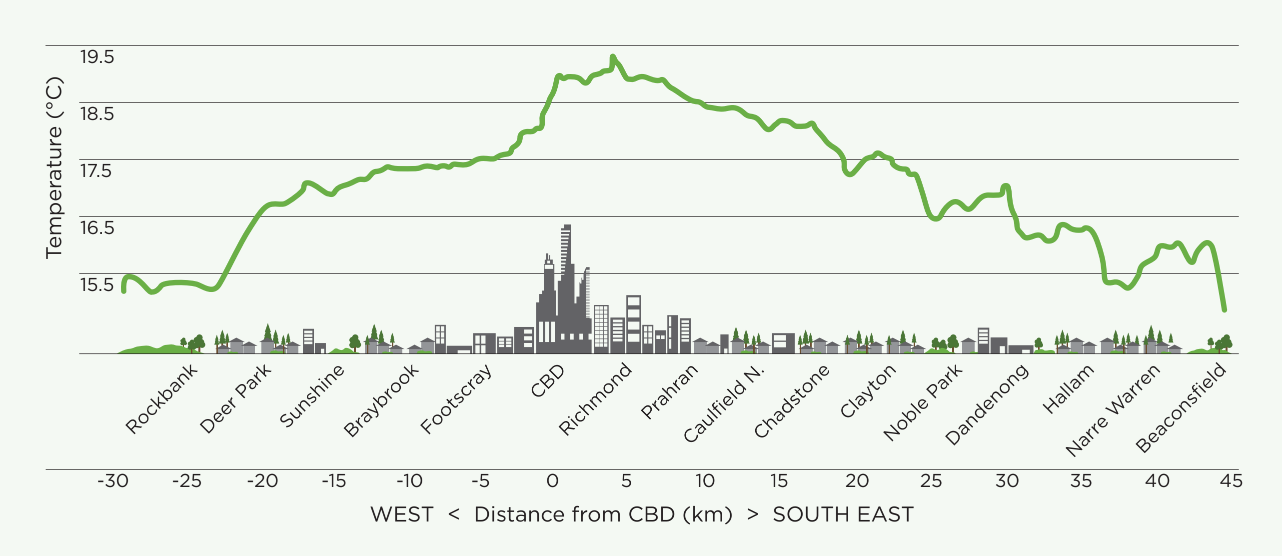
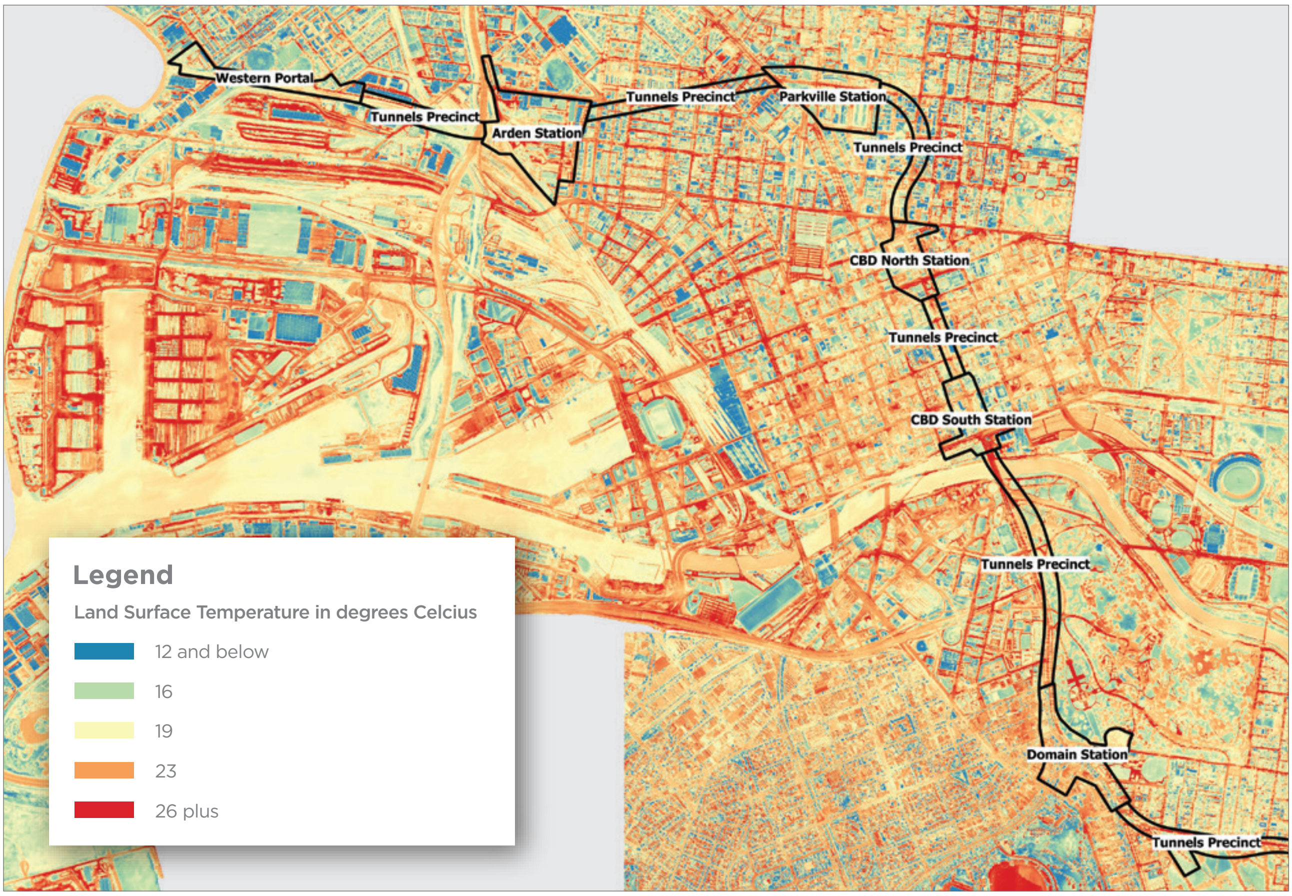
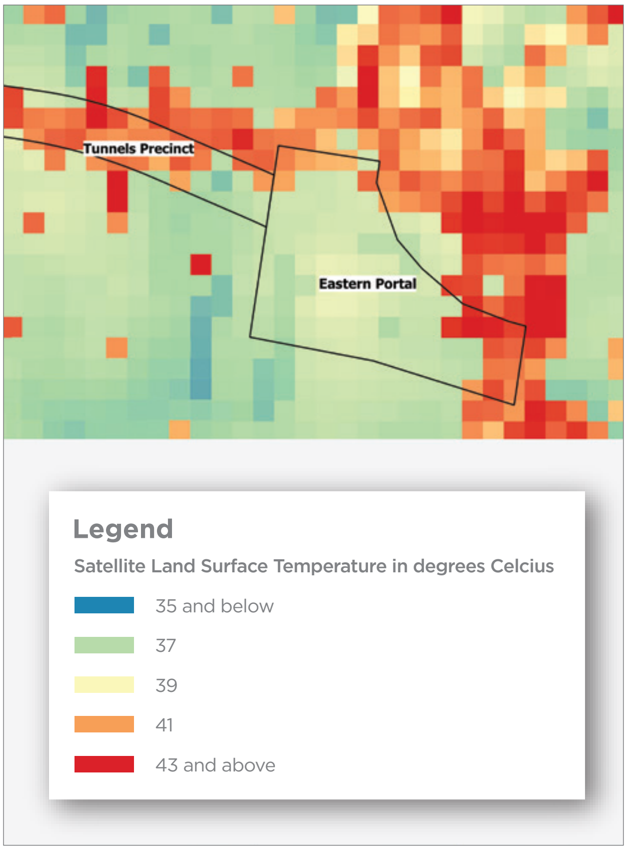


Figure 7: Aerial thermal imaging of the project site (excluding Eastern Portal) identifying localised hotspots. City of Melbourne image taken 24th February 2012 midnight – 2am. City of Port Phillip image was taken 12th March 2013 at 3pm



32 https://www.clearwater.asn.au/user-data/resource-files/planning-for-a-cooler-future-green-infrastructure-guide.pdf.

Figure 8: Satellite Thermal imaging of South Yarra identifying localised hotspots in relation to the eastern portal. Image taken from Landsat 8, 14th January 2014 at 10:30am



7.4 BIODIVERSITY OF PLANTS AND ANIMALS

Biodiversity refers to the records of plant and animal species that have been recorded within 400m of the Metro Tunnel construction zones since 1 January 1996. This analysis indicated there were relatively high levels of biodiversity found around many of the construction zones, with a total of 99 native species out of 161 total, many of which were birds[33]. This is likely to be a significant underestimate of biodiversity at that time, given that plants and invertebrates are distinctly underrepresented in the Victorian Biodiversity Atlas records for this area (but is the best available information to use).

Ten rare or threatened animal species (9 birds, 1 mammal; Table 6) were recorded within 400m of the construction zones in the past 20 years. All of these species are highly mobile and capable of relocating to nearby areas in response to above ground construction activities. These species are in addition to the small burr-grass (plant), Australian Grayling (fish) and Grey Goshawk (bird) listed in the EES. These additional species were not listed in our analysis as they were recorded within a distance of more than 400m from the Metro Tunnel EES boundary (1km (small burr-grass) or 5km (Australian Grayling and Grey Goshawk)).

LINK TO SUSTAINABILITY TARGETS

The urban heat island analysis has been included for reference information only as there is no direct urban heat reduction target included in the *Living Infrastructure Plan*.

33 Victorian Biodiversity Atlas © The State of Victoria. https://vba.dse.vic.gov.au/vba/#/ Accessed 26 July 2016.

Table 5: Overall summary of biodiversity as at 1996 within 400m of MMRP Construction Zones

Taxonomic Group	Native Species	Introduced Species	Total Species
Birds	81	11	92
Mammals	2	0	2
Reptiles	1	0	1
Plants	15	51	66
Grand Total	99	62	161

Table 6: Conservation status of Threatened species recorded within 400m of MMRP construction zones, and the precincts they were recorded near. Status on three lists: EPBC (VU – Vulnerable); Victorian Advisory List (nt – Near Threatened, vu – Vulnerable, en – Endangered), and FFG (L – Listed)

Status	Scientific Name	Common Name	Precincts
nt	Alcedo azurea	Azure Kingfisher	Domain Station
nt	Nycticorax caledonicus hillii	Nankeen Night Heron	CBD North Station; CBD South Station; Western Portal; Linlithgow Ave, Tom's Block
nt	Phalacrocorax varius	Pied Cormorant	Domain Station; Linlithgow Ave, Tom's Block
vu	Aythya australis	Hardhead	CBD North Station; Western Portal; Linlithgow Ave, Tom's Block
vu	Biziura lobata	Musk Duck	Linlithgow Ave, Tom's Block
vu L	Ardea modesta	Eastern Great Egret	Western Portal; Linlithgow Ave, Tom's Block
vu L	Ninox strenua	Powerful Owl	Parkville Station; CBD North Station; Domain Station
vu L	Pteropus poliocephalus	Grey-headed Flying-fox	CBD South Station; Domain Station; Linlithgow Ave, Tom's Block; Fawkner Park; Western Turnback
en L	Ardea intermedia	Intermediate Egret	Western Portal
en L	Oxyura australis	Blue-billed Duck	Linlithgow Ave, Tom's Block

All of these species are also listed in Environment Effects Statement[34], whereby site assessments determined that only the Powerful Owl and Grey-Headed Flying-Fox were likely to use habitat resources within the Metro Tunnel construction zones. This position is supported, as the other eight species are associated with waterways. Given the Living Infrastructure Plan considers new approaches for city sustainability, it has provided supporting information in *Metro Tunnel Best Practice Note 1 Biodiversity Sensitive Urban Design*.

The Living Infrastructure Plan will set out measures to generally improve the quality of habitat for these rare and threatened species within and adjacent to the above ground construction precincts.

This data has been extracted from the Victorian Biodiversity Atlas, and summarised for each precinct identified for potential above-ground construction activities.

LINK TO SUSTAINABILITY TARGETS

This biodiversity of plants and animals analysis ties to the following Sustainability Targets:

+ Total amount of vegetated surface permanently gained post construction must be greater than total amount of vegetated surface area permanently lost.
+ At least 25% of new and reinstated planting areas must consist of diverse, multi-story plantings for biodiversity.

7.5 URBAN SOILS

The Metro Tunnel will excavate sedimentary rock of the Melbourne Formation, which comprises most of the rock beneath much of Melbourne. The tunnels would be located within Melbourne Formation generally between the Arden station precinct and the Yarra River crossing.

Layered soils of varying composition and consistency, interbedded with tongues of basalt, are encountered from the Maribyrnong River to the Moonee Ponds Creek valleys (western portal to Arden station precincts), as well as at the Yarra River crossing.

A layer of generally very stiff sedimentary soil is found overlying the Melbourne Formation from Kings Domain to the Eastern Portal. The tunnels pass through these materials along this eastern section of the project.

Given the entire project boundary is located within the urbanised area of Melbourne the soil profile has been varied by human occupation[35] either by placing material on top of the existing soil profile or excavation of in situ soils and deposition of imported material. Imported fill in decades past has unfortunately introduced contamination and this will all be managed during construction through compliance with the Environmental Performance Requirements.

LINK TO SUSTAINABILITY TARGETS

This urban soils overview has been included for reference information only, as there is no direct soil health outcome target included in the Living Infrastructure Plan. This is because soil health outcomes are very site dependent and more research and guidelines are needed to progress this urban management area[36]. The stormwater, vegetation, and canopy targets will indirectly support soil health outcomes.

34 MMRP Technical Appendix T-Terrestrial Flora and Fauna, in the Table of Threatened Species (Appendix B; p.81-91).
35 http://www.theage.com.au/national/investigations/what-lurks-beneath-victorias-toxic-challenge-20160723-gqc80l.html.
36 Lehmann A, Stahr K (2007) Nature and significance of anthropogenic urban soils. J Soils Sediments 7 (4) 247-260.

7.6 URBAN WATER

The Metro Tunnel will bore under the lower reaches of both the Yarra River and Moonee Ponds Creek. Both of these waterways have been heavily modified and subject to high levels of urban stormwater runoff. Melbourne Water currently rates them as of 'poor' water quality[37] due largely to high nutrients such as nitrogen, phosphorus and heavy metals.

The surface construction areas of the Metro Tunnel are predominantly sealed urban surfaces which create an impermeable boundary that stops water from reaching the underlying soil. Consequently, a significant amount of rainfall runs off these surfaces as stormwater, contributing to disruption and pollution of local waterways and Port Phillip Bay. The reinstatement and creation of new surface landscapes through Metro Tunnel is an opportunity to contribute to an improvement of urban stormwater quality through water sensitive urban design.

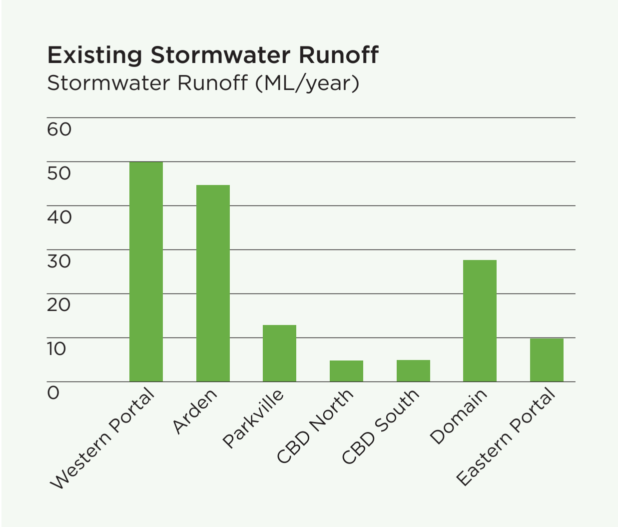
Analysis of the surface construction areas has been conducted using a visual estimate of impermeable area from aerial photography and modelling of stormwater runoff using the MUSIC (water sensitive urban design simulation) tool. It is estimated that currently:

+ the surfaces within the proposed construction areas generate 158 million litres of stormwater runoff per year; and
+ every year stormwater runoff carries 26 tonnes of sediment, 46kg of phosphorus and 365kg of nitrogen. Most of these pollutants will make their way into the Yarra River or Moonee Ponds Creek and eventually into Port Phillip Bay.

The delivery of living infrastructure is an opportunity to both intercept and treat stormwater landing on the project area, and also to use stormwater as a resource for passive irrigation of trees and vegetation.

Treating stormwater arising from the total surface area in construction zones of the Metro Tunnel project to best practice standards will result in the removal of over 21 tonnes of sediment, 20kg of phosphorus and 164kg of nitrogen per year.

Figure 9: Estimated existing stormwater runoff from Metro Tunnel construction areas



The above graph summarises the estimated stormwater runoff from each precinct, highlighting that the largest volumes of stormwater are generated in the Western Portal, Arden and Domain precincts.

LINK TO SUSTAINABILITY TARGETS

This urban water management base case ties to the following Sustainability Targets:

+ Manage stormwater runoff from new or reinstated ground surfaces and roof areas to achieve the best practice water quality performance objectives as set out in the Urban Stormwater Best Practice Environmental Management Guidelines (Victoria).
+ Use rainwater and/or stormwater to provide passive irrigation to all tree plots and vegetated areas to support soil moisture needs.

37 http://www.depi.vic.gov.au/__data/assets/pdf_file/0017/200582/ISC_Part9_Port_Phillip.pdf.

7.7 GROUNDWATER

Groundwater in inner Melbourne generally flows south and south west towards the Yarra River and Port Phillip Bay. The highest groundwater elevations along the tunnel alignment occur in the Parkville area at 25m AHD and the lowest groundwater levels occur in the area of the CityLink tunnels at around -10m AHD[38].

There is evidence that indicates the Yarra River, Moonee Ponds Creek, the Maribyrnong River and the northern part of Albert Park Lake are not groundwater dependent in Metro Tunnel study area. Across Australia, there is a need to improve local knowledge of groundwater conditions to help better manage the likely impacts of future development such as the Metro Tunnel.

For the Metro Tunnel, the source of groundwater impacts could be the construction and to a lesser extent the operation of stations, portals, shafts and tunnels. Hazardous activities in relation to groundwater that could occur during the construction and operation of Metro Tunnel include dewatering of excavations (and associated lowering of the watertable at and away from the excavation – referred to as groundwater drawdown), inflows to structures, and the blocking of natural groundwater flow paths. Groundwater impacts will be managed through compliance with the Environmental Performance Requirements.

LINK TO SUSTAINABILITY TARGETS

This groundwater overview has been included for reference information only, as there is no groundwater outcome target included in the *Living Infrastructure Plan*. This is because groundwater research, modelling and monitoring (beyond the scope that is set out in Environmental Effects Statements) has not yet evolved to establish new best practice approaches for enhancing the health of groundwater systems and their groundwater-dependent ecosystems[39]. The application of the EPRs along with the stormwater and surface water targets will indirectly support groundwater health outcomes.

38 http://metrotunnel.vic.gov.au/__data/assets/pdf_file/0018/51048/MMRP_Chapter-18_Groundwater.pdf.
39 Lavoie R, Joerin F, Vansnick J-C, Rodriguez MJ (2015) Integrating groundwater into land planning: a risk assessment methodology. *Journal of Environmental Management* 154 358-371.

Figure 10: Map identifying depth of water table over the Metro Tunnel project area. Areas with the shallowest water table (within 6m of the surface) are shown in dark blue (Melbourne Metro Rail Project Environment Effect Statement, May 2016 Technical Appendix O)

8. STRATEGIES

To deliver the vision and targets, the *Living Infrastructure Plan* sets out strategies for three focus areas: urban ecosystems, urban soils, and urban water.

METRO TUNNEL LIVING INFRASTRUCTURE PLAN

Vision: Metro Tunnel will demonstrate world leading excellence to create a living infrastructure legacy for a more liveable Victoria.

The Living Infrastructure Plan will guide the creation of urban landscapes that:

+ are more biodiverse, healthy and climate change resilient
+ successfully provide ecosystem services that improve the urban environment
+ add amenity and enhance local character
+ support liveable, active, healthy and connected communities
+ provide inspiration, opportunities and case studies to support increased uptake of living infrastructure initiatives in future urban planning, design, engagement and management.

Targets

Double tree canopy – Deliver increased biodiversity habitat – Deliver best practice urban water management

Living Infrastructure Measures and Opportunities

Urban Ecosystems

+ Increased habitat links including pollinator pathways.
+ Biophilic design in & around stations.
+ Biodiversity-friendly design for landscapes.
+ Species selection for resilience & diversity.
+ Tree protection.

Urban Soils

+ Best practice soil standards to maximise healthy canopies for urban heat reductions.
+ Soil for sequestration.
+ Soil to maximise soil health and biodiversity.
+ Soil monitoring for climate resilience.

Urban Water

+ Best practice stormwater quality treatment in design.
+ All tree plots to filter stormwater.
+ All vegetation supported by passive irrigation.
+ All drainage and alternate water sources designed for climate resilience.

Engagement, Monitoring and Knowledge Sharing

Draw from, and support, community knowledge on habitat and local link projects

Draw from, and support, applied research projects to grow practitioner knowledge for this and future projects

8.1 URBAN ECOSYSTEMS

It seems easy to underestimate the biodiversity value of cities, however, an understanding of their valuable ecosystem role is increasingly emerging. For example, one recent study has shown that Australian cities support substantially more nationally threatened animal and plant species than all other non-urban areas on a unit-area basis. Thirty per cent of threatened species were found to occur in cities[40].

Delivering healthy living infrastructure in urban areas requires actions that work to reduce the two key threats to biodiversity in urban landscapes:

1. Direct loss of habitat, which can often proceed undetected through an accumulated loss of individual features (e.g. removing an established tree) or carving away at the remaining areas of habitat ("death by a thousand cuts")[41].

   For the Metro Tunnel, preventing loss of habitat requires measures to ensure limited tree removals, and efforts to minimize construction zones to limit vegetation and topsoil disturbance.

2. Reductions in the quality of existing habitats, which can occur through obvious impacts such as weed invasion, lack of supportive management, or detrimental impacts resulting from human activities; as well as less obvious impacts such as the presence of, noise, heat or artificial light pollution[42]. The increasing isolation of habitat areas can also erode the quality of existing habitats as the landscapes between them become more intensively developed and movements and connections between sites become rarer[43].

   For the Metro Tunnel, increasing the quality and connection between habitat areas in inner Melbourne requires measures that allocate more space for flora and fauna to grow (including ground level, underground and aboveground opportunities), more links between habitats for pollination, more suitable vegetation for shelter or foraging (structural complexity and plant species diversity), and novel artificial habitat options[44] to increase species success and pollination[45].

Efforts to limit the above threats to urban ecosystems will in turn reduce harmful impacts in landscape including air, water, heat, soil and light pollution[46] to progressively improve resilience[47], health and wellbeing outcomes for all species. While these key threats are well known and understood, there is a pressing knowledge gap around the most effective actions and instruments we can incorporate into the planning, design and management of urban landscapes to reduce these threats[48].

Please note, the urban ecosystem measures in the following table relate to landscape works and complement the regulatory Environmental Performance Requirements for flora and fauna, arboriculture, landscape and visual outcomes; and the Metro Tunnel – Urban Design Strategy.

40 Ives, C. D., Lentini, P. E., Threlfall, C. G., Ikin, K., Shanahan, D. F., Garrard, G. E., Bekessy, S. A., Fuller, R. A., Mumaw, L., Rayner, L., Rowe, R., Valentine, L. E. and Kendal, D. (2016), Cities are hotspots for threatened species. Global Ecology and Biogeography, 25: 117–126.
41 Whitehead AL, Kujala H, Wintle BA (2016) Dealing with Cumulative Biodiversity Impacts in Strategic Environmental Assessment: A New Frontier for Conservation Planning. Conservation Letters http://onlinelibrary.wiley.com/doi/10.1111/conl.12260/pdf.
42 Ikin K, Le Roux DS, Rayner L, Villaseñor NR, Eyles K, Gibbons P, Manning AD, Lindenmayer DB (2015). Key lessons for achieving biodiversity-sensitive cities and towns. Ecological Management & Restoration, 16 206-214.
43 Harrison T, Winfree R (2015) Urban drivers of plant-pollinator interactions. Functional Ecology 29: 879–888. doi:10.1111/1365-2435.12486.
44 Growing Green Guide: A guide to green roofs, walls and facades in Melbourne and Victoria http://www.growinggreenguide.org.
45 Office of Environment & Heritage NSW Conservation Management Notes "Assessing Wildlife Habitat" http://www.environment.nsw.gov.au/resources/cpp/AssessHabitat.pdf.
46 Hahs AK and McDonnell MJ (2014) Extinction debt of cities and ways to minimise their realisation: A focus on Melbourne. Ecological Management and Restoration 15:102-110 doi: 101111/emr12112.
47 McPhearson T, Andersson E, Elmqvist T, Frantzeski N (2015) Resilience of and through urban ecosystem services. *Ecosystem Services* 12 152-156.
48 McDonnell MJ, Hahs AK (2013) The future of urban biodiversity research: Moving beyond the 'low-hanging fruit'. Urban Ecosystems 16:397-409.

Measures for Urban Ecosystem Improvement	
Principle	**Measures**
1. Protect existing vegetation and seek ways to increase habitat links and pathways.	**A. Tree protection is maximised and replacement plantings will be undertaken to support the Metro Tunnel target to 'double canopy cover by 2040'**. Tree protection practices are to comply across the whole project site in accordance the with the City of Melbourne's *Tree Protection Guidelines*[49], and *AS* 4970: Protection of Trees on Development Sites. This also applies to trees that could be negatively impacted by construction works that are not in the project boundary. Environmental Performance Requirements relating to Arboriculture provide additional regulatory guidance to ensure tree protection.
	B. The primary program to help deliver the 'double canopy cover by 2040' target is a commitment to plant two new trees to replace every tree removed. The trees will be planted to best practice conditions. The location of tree plantings will be arranged to maximise the living infrastructure benefits that the tree can provide. Proposed planting locations are to be supported by an outline of any ecosystem service benefit it provides; including urban heat island reduction impacts, stormwater quality benefits, air quality benefits, habitat enhancement and pollinator links. See further information in *Metro Tunnel Best Practice Note – Tree Location*. Please note, this does not apply to the 1 for 1 replacement tree as its location is already determined.
	Identified Opportunities
	C. Consideration will be given to **habitat links** that can help grow corridor connections for pollinators, fauna, walkers and cyclists.
	D. Where the project directly interfaces Moonee Ponds Creek, consideration will be given to opportunities to any partner initiatives seeking vegetation links 'to and along' Moonee Ponds Creek to enhance local connection to **the scarce (but emerging) biodiversity and nature opportunities** that lie in the inner West.
	E. Consideration will be given to the provision of **temporary containerised urban forest sites** near constructions zones to help improve air quality, thermal comfort, habitat and amenity impacts. It is recommended this be supported with a monitoring program to document the impacts and to support guidelines for future projects.

49 http://www.melbourne.vic.gov.au/SiteCollectionDocuments/Tree_Retention_and_Removal_Policy.pdf.

Measures for Urban Ecosystem Improvement	
Principle	**Identified Opportunities**
	F. Consideration will be given to the **establishment of green roofs and green walls for ongoing or temporary city benefit**. These could be located within and adjacent to the construction zones, or within close walking distance to support public access to vegetation during construction works. The benefits of green roofs and walls for capturing stormwater, insulating buildings and providing living infrastructure benefits to people and biodiversity, are increasingly being recognised and this proposal addresses a gap in opportunities for the public to experience a rooftop garden. Any green walls, roof and facade details are to be specified in accordance with the principles and guidance of the *Growing Green Guide* and accounting for community input.
	G. Consideration will be given to the potential to **increase habitat links to support 'pollinator pathways'**. This can improve corridor connections for pollinators, fauna, walkers and cyclists. Project opportunities include: + Establishing **habitat-led 'pollinator pathways'** along Pelham St, Parkville, and Albert St in South Yarra. Subject to detailed design, the Pelham St corridor could connect Haymarket Roundabout, University Square, Lincoln Square, Argyle Square and Carlton Gardens; while the Albert St corridor would connect Domain Parklands, the reinstated Boer War Memorial Park with Albert Park. + Establishing an on-road high quality **bike lane-led 'pollinator pathway'** through inner Melbourne that 'follows the tunnel'. Subject to detailed design, this route can connect the emerging habitat of Moonee Ponds Creek, via passively watered tree plots along Arden-Wreckyn-Grattan Streets, linking to Swanston St and the Yarra River before moving down St Kilda Road to support habitat enhancement to Albert Park Lake and Fawkner Park. Bike lane design will incorporate habitat links however the best practice layout must ensure a smooth and safe route for cyclists.
	H. Design of new station structures will give consideration to incorporation of vegetation and demonstration of **biophilic design initiatives**. This can be achieved by minimising station footprint wherever possible and/or incorporating surface plantings, green roofs, green walls or green facades. Biophilic design that maximises connections to nature through internal landscaping and provision of viewlines that help people see and feel closer to nature. Biophilic design guidelines are provided in Metro Tunnel: Stations Biophilic Design Guidelines.

Measures for Urban Ecosystem Improvement	
Principle	**Identified Opportunities**
2. Increase the quality of urban habitat to support biodiversity and human well-being.	**A. Surface planting conditions** are to support healthy ecosystem opportunities by ensuring early consideration of solar access, passive irrigation, habitat links, and health and wellbeing benefits. All vegetation plots are to be allocated as early as possible in the design phase to address these criteria.
	B. Design of all vegetation will **apply biodiversity sensitive design principles** and account for community input. The composition and placement of vegetation will influence the ability of the landscape to deliver positive outcomes for people and biodiversity. This includes greater opportunities for people to connect with nature through proximity, seating, signage and other links. *Metro Tunnel Best Practice Note – Biodiversity Friendly Urban Design* provides recommendations to support this measure.
	C. Species selection for planting across the project area to enhance habitat for existing and future biodiversity, reflect changing climate and future urban conditions. Tree and vegetation selection and planting will be undertaken by the relevant local government authority in partnership with MMRA to ensure the selections are consistent with Council policies.
	D. Provide diverse multi-storey plantings, nest boxes, bee hotels, logs and warm rock crevices to support fauna and enhance biodiversity. These novel habitats should be created in the context of fauna movement and ideally reuse local materials. Novel habitat design information is provided in *Metro Tunnel Best Practice Note = Biodiversity Friendly Urban Design* of the Living Infrastructure Plan. Fauna support information provided during tree removal works in the form of wildlife rescue support, rehoming options, and staged tree removal is provided in *Metro Tunnel Best Practice Note – Wildlife Transition in Construction Areas* of the Living Infrastructure Plan.
	E. The handover process should include a **long term maintenance plan for vegetation**, including maintenance in the initial two years. This will increase the likelihood of delivering well performing landscapes and ensures there is no gap in care between temporary and ultimate land managers. The maintenance plans are likely to include input from ultimate land managers, contractual agreements and maintenance funding arrangements, onsite training information sessions, handbooks and operational manuals, and asset management data. This is to be linked to WSUD asset maintenance commitment.

The urban ecosystem measures set out in this Living Infrastructure Plan support the Metro Tunnel Project Sustainability Targets and are supplementary to the criteria and requirements set out in the Environmental Performance Requirements forming part of the Environmental Management Framework.

8.2 URBAN SOILS

Emerging evidence is helping us realise that soil is one of the most underappreciated forms of living infrastructure; helping us to prevent floods, withstand droughts, support biodiversity, reduce pollution and recycle our valuable nutrients.

Cities can do more to restore the natural soil-water balance and improve soil health. We are rapidly learning more about soils: the impact of heat islands on soil temperature, changing soil quality and soil health; and the value of biochar for soil health while at the same time sequestering carbon; and the importance of soil organism diversity in optimising nutrient recycling.

The root zones of trees are where most of our urban infrastructure is spread, including services, pavements and compacted road base. Systems, standards and processes need to be developed to deal with these multiple, competing and growing needs.

Root growth is commonly limited by drought, waterlogging, hypoxia, soil compaction, salinity and high concentrations of heavy metals. This can result in street tree roots proliferating in microsites that are more favourable for growth. Studies are showing that 'structural soils' are valuable in extending the rooting zone below the pavement.

For the Metro Tunnel Project, there is an opportunity to provide greater climate resilience by increasing the water storage ability of the soil, which in turn helps combat flooding and drought impacts[50], along with preserving and restoring soil biodiversity[51] wherever possible to support ecosystem health, disease regulation, and carbon sequestration[52].

The Metro Tunnel will have us burrowing below the city to create critical infrastructure to lessen disruption above ground. This provides a great opportunity to increase our knowledge and communication around critical urban soil issues.

The approach taken in this plan focuses on development of soil specifications to optimise landscape performance. Specifications will apply to disturbed and recycled soils as well as imported soils. Guidelines will be developed for stockpile management and re-use of site soil. Optimising soil properties and protection of site soils aim to link soils to a range of sustainability targets including water quality, biodiversity, and amenity.

Please note, the measures below relate to landscape works and complement the regulatory Environmental Performance Requirements for soil management and soil contamination that apply to all tunnel construction works.

50 Chen Y, Day S, Wick A, McGuire K (2014) Influence of urban land development and subsequent soil rehabilitation on soil aggregates, carbon, and hydraulic conductivity. *Science of the Total Environment* 129-336.
51 Philpott S, Cotton J, Birchier P, Friedricj RL, Moorhead LC, Uno S, Valdez M (2014) Local and landscape drivers of arthropod abundance, richness, and trophic composition in urban habitats. *Urban Ecosyst* 17: 513-532.
52 Rawlins BG, Harris J, Price S, Bartlett M 'A review of climate change impacts on urban soil functions with examples and policy insights from England UK *Soil Use and Management* 2013.

Measures for Urban Soil Improvement	
Principle	**Measures**
1. Protect existing soils to support vegetation and microbial life which will ultimately assist with more effective landscaping at the end of the project.	**A.** Soil preservation is to be sought wherever possible by ensuring any areas or edges of the site not essential to construction are to be protected from compaction, soil relocation, weed exposure throughout the life of the project. An opportunity exists to grow community understanding of the importance of soil ecosystem health by providing signage about this at any pockets of undisturbed soil.
2. Incorporate fit-for-purpose soil preparation standards and management plans for all new and reinstated landscapes.	**A.** Soil preparation and/or soil rehabilitation for all areas is to be undertaken with site specific planning to ensure the soils are fit for purpose (including the needs of the vegetation it will be supporting, the activity of people using the site, and the current and future climate conditions). Evidence-based models are required to ensure delivery of this fit-for-purpose approach to soil preparation. Examples include processes set out by Leake & Haege (2014), Calkins (2012) and Craul and Craul (2006). Soil preparation is supported by *Metro Tunnel Best Practice Note – Soils for Landscaping* along with soil specifications, as necessary to support growing media for street tree pits (including pits with structural soils and stormwater harvesting), garden areas, podium plantings, native planting, amenity turf, green walls and green roofs.
	B. Landscaping soil management plans need to be developed in conjunction with landscaping construction plans to ensure the project life cycle of soil management is achieved starting from protection during construction, post-construction restoration and future management and maintenance. Soil management plans must also consider stockpile management to preserve the integrity of excavated soils. An opportunity exists for more holistic landscaping soil management plans incorporating soil contamination; soil preservation and biodiversity; soil nutrient; and soil hydraulic conductivity management solutions.

Measures for Urban Soil Improvement	
Principle	**Measures**
3. Install soil volumes for trees to optimise future canopy growth to help meet canopy cover targets.	**A. Maximise underground planting conditions** to support healthy urban tree growth with better soil, access to water, better drainage and more space for tree roots. The project requires all areas under footpaths, verges and garden beds to support root growth via quality fit-for-purpose soil preparation including structural soils. Permeable surface treatments directly surrounding the trees up to their trunks must be installed and best practice standards areas of permeable surface must be applied (e.g. 2.89m^2 in size at a minimum). To allow for subsidence effects and to provide direct access for irrigation during establishment, surface treatments shouldn't be installed immediately (installation of the final surface two years post-planting is regarded as good practice).
	B. Best practice soil volume for each tree must be approximately one third of projected canopy area prepared to a depth of 1m as per *Urban, James (2008)*, or 1.5m if the tree plot is positioned over an underground structure. For example, a projected tree canopy area of 74m^2 would require 28m^3 of soil volume at a depth of 1m. Changing to a smaller species of tree is sometimes not possible due to heritage and planning requirements. In this situation, the soil volume may be less than one-third of the projected canopy following assessment of climate, soil type, tree type, irrigation / water capture and shared soil volumes. Street trees are best supported by lateral trenches and structural cells under footpaths. Further guidance is provided in *Metro Tunnel Best Practice Note – Soils for Landscaping.* The allocation of soil volume space is to be shown in detailed landscape plans prior to works commencing to ensure the underground services can also be accommodated without compromising root growth and minimising conflict between the two.

The urban soil measures set out in this *Living Infrastructure Plan* support the Metro Tunnel Sustainability Targets and are supplementary to the criteria and requirements set out in the Environmental Performance Requirements forming part of the Environmental Management Framework.

8.3 URBAN WATER

Living infrastructure has a direct and co-dependent relationship with water. Trees, vegetation and soils depend on access to water to remain healthy. Equally, trees, vegetation and soils can play an important role in managing rainwater and stormwater in an urban environment; by slowing and storing runoff and providing filtration and treatment.

In central Melbourne, there are key urban water challenges that integrated design of living infrastructure can assist with:

+ **Sustainable water supply:** The extended millennium drought demonstrated the devastating effect that low rainfall and restricted irrigation can have on urban trees and vegetation, with a large proportion of Melbourne's tree stock suffering serious decline. Water authorities and councils in Melbourne and in Victoria more widely, are working to secure a broader portfolio of water supplies and make better use of water resources. In an urban context like Melbourne, capture of alternative sources of water including stormwater and recycled water are major opportunities to diversify water supply.

  The primary source of water for Living Infrastructure in the Metro Tunnel Project area will be stormwater, where runoff from adjacent roads and paved areas can be passively directed into vegetated soil areas[53].
+ **Stormwater treatment:** Stormwater runoff from urban areas, such as where the Metro Tunnel is being constructed is a contributor to degradation of the quality of local waterways (Moonee Ponds Creek, Maribyrnong River, Yarra River) and of Port Phillip Bay, which adversely affects their recreational value and the natural ecosystems that depend on them[54].

  Where works are taking place on the surface to create new infrastructure or reinstate existing urban areas, there is an opportunity to integrate living infrastructure that also filters and treats stormwater runoff. Water sensitive urban design principles include utilising vegetation and soils to trap sediment and heavy metals, and take-up nutrients, therefore removing pollutants from our aquatic environments.
+ **Drainage capacity and flood mitigation:** New and reinstated urban landscapes can also increase drainage capacity and storage, helping to manage storm flows and reduce flood risk.

  The Elizabeth Street Catchment, which includes the proposed stations at Parkville, CBD North and CBD South has been categorised by Melbourne Water as being at 'Extreme Flood Risk', and works in this catchment and in the urban area more broadly can assist in reducing flood risk by creating greater canopy cover and soil areas where runoff can be intercepted, slowed and stored[55].
+ **Groundwater:** Environmental Performance Requirements are set to protect both groundwater and surface water health. The importance of groundwater health is often underestimated in urban environment despite its vital role in ecological dynamics.

  Groundwater typically feeds wetlands, rivers and lakes, affecting base flow and leading to significant impacts on riparian habitats and species. Substances present in groundwater will reach such environments and can lead to changes in nutrient input in lakes and other variations. Proper site and stormwater management system design can prevent most groundwater contamination because most contaminants adhere to fine soil particles as long as runoff infiltrates slowly.

  In urban environments, groundwater levels are reduced by soil sealing with impermeable surfaces and by recent efforts to prevent leaking pipes in our water supply systems. Basement construction and tunnelling projects such as the Metro Tunnel also disrupts aquifers and groundwater flows requiring careful management of both consequences for both living infrastructure and grey infrastructure.

Please note, the following water measures and opportunities complement the water conservation goals that will be delivered for building and tunnel works in accordance with Green Star and ISCA Rating Tool requirements. The measures relate to landscape works and complement the regulatory Environmental Performance requirements for water management that apply to all tunnel construction works.

53 Calkins, M (ed). (2012) The Sustainable Sites Handbook. A complete guide to the principles, strategies and best practices for sustainable landscapes. Wiley.
54 https://www.clearwater.asn.au/user-data/resource-files/2016_08-waterways-issues-paper-pub.pdf.
55 https://www.clearwater.asn.au/resource-library/publications-and-reports/mainstreaming-flood-resilience-in-cities.php.

Measures for Urban Water Improvement	
Principle	**Measures**
1. **Incorporate Water Sensitive Urban Design (WSUD) in new and reinstated surfaces.**	A. **All stormwater runoff from new or reinstated ground surfaces and roof areas to achieve the best practice water quality performance objectives** as set out in the Urban Stormwater Best Practice Environmental Management Guidelines (Victoria)[56]. Currently, these water quality performance objectives are: (i) Suspended solids – 80% retention of typical urban annual load. (ii) Total nitrogen – 45% retention of typical urban annual load. (iii) Total phosphorus – 45% retention of typical urban annual load. (iv) Litter – 70% reduction of typical urban annual load. The use of Water Sensitive Urban Design (WSUD) assets and techniques (e.g. raingardens, roof gardens, permeable paving, swales etc) provides an opportunity to use soils and vegetation to manage water and to support Living Infrastructure. Water sensitive urban design features must be designed in accordance with the Melbourne Water's WSUD Guidelines and WSUD Engineering Procedures. These requirements are further supported by the prevention of erosion, dust and runoff during works as set out in EPRs relating to construction management procedures. Modelling of stormwater treatment performance of new and reinstated areas will be completed using a tested, and proven method of modelling treatment runoff to achieve the stormwater treatment objectives (eg: the MUSIC tool following the Melbourne Water MUSIC Guidelines). Modelling assumptions and results will be submitted with detailed landscape design plans.
	B. **All tree plots and vegetation planting in constrained sites must incorporate passive stormwater irrigation using water sensitive urban design.** Any circumstances where this does not apply will be supported by modelling and plans demonstrating extraneous circumstances. Different passive irrigation standards and trials will be included across the project. The performance of the plots will be monitored in partnership with a research body to ensure knowledge is shared with practitioners for future projects so that passive irrigation and soil treatment continues to grow as a stormwater management technique. Planting and soil volumes will be designed to be supported by rainwater and stormwater runoff from adjacent surfaces for irrigation and will avoid reliance on active irrigation using potable water, however where it is required, supplementary irrigation will be included in design and maintenance procedures in accordance with *Metro Tunnel Best Practice Note – Design Details for Passive Irrigation* supported by the *Best Practice Guidelines for Functional Open Space (2015)*[57].

56 http://www.epa.vic.gov.au/business-and-industry/guidelines/water-guidance/urban-stormwater-bpemg.
57 Smart Water Fund, City West Water, Irrigation Australia, Sports Turf Association (2015) Best Practice Guidelines for Functional Open Space https://www.clearwater.asn.au/user-data/research-projects/swf-files/bpg-final.pdf.

Measures for Urban Water Improvement	
Principle	**Measures**
	C. Vegetation and soils in water sensitive urban design features require the following design considerations: (i) An impervious catchment area of at least 10 times the tree canopy area helps ensure effective levels of passive irrigation and stormwater treatment. Where a larger canopy is desired, top-up irrigation is required during dry periods to supplement passive irrigations from stormwater. (ii) A low nutrient soil mix is used to avoid nutrients being leached into the drainage system. (iii) Soils are structurally stable to prevent erosion and collapse. (iv) Soils have a saturated hydraulic conductivity less than 200mm/hr. (v) Trees and vegetation are selected that are tolerant of drought conditions and tolerant of temporary inundation during rain events. (vi) Trees and vegetation are selected that provide effective nutrient removal in addition to other requirements outlined in the vegetation specifications.
	D. Maintenance and training is integrated into the handover process to maximise the success rate of water sensitive urban design and planting installations. Best practice design for maintenance and establishment of maintenance protocols is required (for example, *City of Port Phillip Targeted Maintenance for WSUD Assets*[58] and *Zero Additional Maintenance WSUD Handbook*[59]). Maintenance information should be provided for the end-user. For best success, it is recommended that on-site sessions with at least three attendees (representing different roles in asset management) be held. Ideally, these on-site sessions will be held at a time during construction to best demonstrate the function of the asset as this will maximise understanding, connection and stewardship of the asset. Asset details and their maintenance requirements are should be listed by the contractor in a format that is compatible with the asset management procedures of the end user.

58 https://www.clearwater.asn.au/resource-library/publications-and-reports/city-of-port-phillip-targeted-maintenance-for-streetscape-wsud-assets.php.
59 https://www.clearwater.asn.au/resource-library/publications-and-reports/zero-additional-maintenance-water-sensitive-urban-design-zam-wsud-handbook.php.

Measures for Urban Water Improvement	
Principle	**Identified Opportunities**
2. Explore opportunities to support alternative water supplies.	**A. Consideration will be given to repurposing water storage tanks, water treatment facilities and pipework** used in construction for temporary water supply a for permanent legacy use. Examples of possible initiatives could include the permanent installation of underground water storage tanks which are utilised as a balancing storage for water supply during construction and which can be utilised as part of an alternative water supply scheme in the future, storing seasonal resources such as rainwater and stormwater.
	B. Consideration will be given to installation of new underground water storage tanks or transfer pipework in excavated areas created during construction. For example, excavated routes created during construction or for new utilities required to support the construction or operation of the project may provide an opportunity to introduce new non-potable water distribution mains. Opportunities should be discussed with project stakeholders to define and coordinate delivery of integrated schemes.
	C. Consideration will be given to facilitation of new alternative water supply schemes to supply stations via a third pipe supply. Each station may include the direct installation of alternative water supplies to meet the potable water reduction target. Facilitation of the provision of alternative sources in the future should also be enabled through the inclusion of third pipe non-potable water connections for major non-potable water uses such as toilet flushing and vegetation irrigation. Councils have advised of stormwater harvesting project collaboration ideas that can be considered as part of the project design to help meet environmental targets. One such example is Albert Park Stormwater Harvesting Project currently being developed by the City of Port Phillip. Where alternative water sources are being used for non-potable supply, design of treatment and supply systems should be in accordance with relevant guidelines, including *Guidance on use of Rainwater Tanks* (Enhealth)[60] for rainwater harvesting, and *National Water Quality Management Strategy: Australian Guidelines for Water Recycling*[61] for stormwater harvesting and recycled water supply.

The urban water measures set out in this *Living Infrastructure Plan* support the Metro Tunnel Project's Sustainability Targets and are supplementary to the criteria and requirements set out in the Environmental Performance Requirements forming part of the Environmental Management Framework.

60 http://www.health.gov.au/internet/main/publishing.nsf/Content/0D71DB86E9DA7CF1CA257BF0001CBF2F/$File/enhealth-raintank.pdf.
61 https://www.environment.gov.au/system/files/resources/044e7a7e-558a-4abf-b985-2e831d8f36d1/files/water-recycling-guidelines-health-environmental-21.pdf.

9. ENGAGEMENT AND KNOWLEDGE SHARING

The Metro Tunnel Project is a complex project not only from an infrastructure design and construction perspective, but also because it is dealing with multiple landowners, land users and agencies over a long construction period. This requires the support of local government, State agencies and private delivery partners to help deliver the project in the way that best protects and improves outcomes for the community.

Evidence shows that the success for these projects is greatest when projects seek positive outcomes across short, medium and longer time frames[62]. Large scale projects should give equal weightings to long term challenges and short term construction impacts. Three of these priority long-term issues include dealing with Melbourne's population growth, long term transport challenges, and impacts caused by climate change.

Trust is shown to be a fundamental key to success for stakeholder relationships[63]. Given the complexity of urban development projects, the willingness to be open with early engagement and collaboration between project leaders and stakeholders can help to grow trust. The challenge in delivering this approach can be the complexity of the project and ensuring relevant project information can be shared as early as possible.

Improvements have been made in recent years for understanding and allowing complex projects to be designed with flexibility that can best respond to stakeholders needs over time. Evidence is demonstrating that a focus which gives stakeholders opportunities to change and co-evolve will bring out the greater potential[64]. To help drive this approach, it is best to focus on an alignment of purpose and the realising of joint benefits.

Urban practitioners from multiple disciplines (ranging from urban design, engineering, transport planning, and conservation) dealing with the rapid expansion in knowledge and expertise needed for complex city planning projects has shown the need for more practical guidelines, training, case studies and knowledge sharing. It is critical to invest in capturing and sharing the knowledge of these city-shaping projects.

One of the critical new approaches to community engagement, connection and knowledge is the application of a placemaking approach. Placemaking ideally stems from the community, but for a project like Metro Tunnel, there are opportunities to initiate placemaking principles via temporary spaces. By leading with a strong sense of place, the community can help direct and support projects helping with decision-making and long term stewardship and connection to place[65].

IDENTIFIED OPPORTUNITIES FOR COMMUNITY ENGAGEMENT

a) **Transparent communication** around the impact of the Metro Tunnel Project on the urban forest is supported, including opportunities to inform the community on urban biodiversity and urban ecosystems. After determining ownership of removed trees, an opportunity exists for community members to provide ideas on their reuse and repurposing. Project plans can consider options ranging from incorporating logs into future landscaping for habitat or play purposes, or turning into biochar or mulch as a soil improvement.

62 Harari, O. (1997). Looking beyond the "vision thing." Management Review, 86(6), 26-29.
63 Bresnan M & Marshall N (2000) Building partnerships: case studies of client constructor collaboration in the UK. Construction Management & Economics 18(7) 819-832.
64 Vaagaaser AL and Eskerod P (2014) Stakeholder Management Strategies and Practices During a Project Course Project Management Journal Vol. 45 No 5 71-85.
65 Chapin, F.S.III, et al., 2012. Design principles for social-ecological transformation toward sustainability: lessons from New Zealand sense of place. Ecosphere, art40, 3 (5), 1–22.

b) **Placemaking engagement and consultation** is supported as a mechanism that helps people pause, reflect, consider, and share local knowledge in different temporary and permanent landscape solutions[66]. This in turn helps community provide oversight in the care of local landscapes because they have a better value and understanding of that place.

The Metro Tunnel Project can focus placemaking opportunities around living infrastructure and biophilic design opportunities. For example, safety hoardings can create space, messaging and support for greenery, structures can host roof gardens for education and consultation benefits.

c) **Landscaping and planting involvement by the community** is supported to help draw upon the expertise of the local users, and to ensure that local communities have a connection and sense of ownership with new landscapes.

Opportunities for local schools or community groups to help with understorey planting and stewardship is an engagement opportunity. Workshops with secondary students can support knowledge growth about urban water and microclimate interactions and high-quality tree planting, and studio courses with tertiary students can consider the role of temporary hoardings and placemaking to help grow local connections and stewardships.

d) **An opportunity exists to apply an integrative design process** to deliver landscapes that are not only 'fit for purpose' but also beautiful, functional and valued by the community. For the Metro Tunnel, the integrative design team can involve the contractors, local government and other key stakeholders, as well as a collection of professionals who can bring their expertise in biophilic design, living infrastructure, human health and wellbeing, sustainable practices, and design, construction and maintenance. It will also include design input from local people who use the space and its surrounds as these end-users hold critical knowledge that will help spaces work better.

This will also include biophilic design features of railway station design that create connections to nature. Stakeholder participation can be an effective way to capture local knowledge to inform better project outcomes and involve the community in the planning and delivery of the infrastructure.

MONITORING METRO TUNNEL'S LIVING INFRASTRUCTURE INITIATIVES

e) **Monitoring will measure, promote and learn from the success of the project.** The monitoring will also help identify and correct any trials that are not reaching performance needs and will support a flexible and evolving process of learning which is needed when applying world leading approaches.

Such monitoring opportunities have been mentioned throughout this Living Infrastructure Plan and include the monitoring of:

+ tree pits and trenches trials for avenue tree planting
+ multi-layered vegetation in public space
+ biodiversity in soils in urban parks, plazas and tree plots
+ high soil preparation standards for tree plots and
+ soils for stormwater responses.

66 http://www.thenatureofcities.com/2016/07/03/accessing-urban-environmental-education-opportunities-via-green-infrastructure/.

OPPORTUNITIES FOR COLLABORATION FOR PRACTITIONER KNOWLEDGE GROWTH

f) **Urban ecosystem knowledge growth via onground project opportunities.** Some ideas from stakeholders that provide beneficial living infrastructure outcomes include:

   + a 'Short-finned Eel' project to learn more, protect and showcase Melbourne's fascinating eel population that lives beside and below us in the stormwater system even in our highly urbanised environment
   + an 'Urban Biodiversity and Ecosystem Monitoring' project to capture the knowledge and initiatives of Metro Tunnel related to the new habitat conditions and their ability to support plant and animal diversity, in order to inform development processes and provide guidelines for future developments.

   These projects provide valuable opportunities to connect and learn from traditional and current Indigenous people and their knowledge of country.

g) **Urban soils knowledge growth opportunities via trial projects and systems.** Some ideas that have been suggested by research and practitioner alliances that provide beneficial living infrastructure outcomes include:

   + trials of soil sequestration and enhancement via the use of biochar
   + improvements in the design of growing media for tree pits to capture store and filter stormwater and
   + new tools and systems to support soil contamination knowledge to help ease the inconsistencies that delay and prevent most projects.

h) **Urban water knowledge growth opportunities via trial projects and systems.** Some ideas that could provide beneficial living infrastructure outcomes include new tools and systems to support and collate groundwater knowledge to help increase practitioner knowledge, inform guidelines and decision support tools, that will all lead to progressive improvement of groundwater management. This is increasingly important as our cities deal with population growth and climate change.

10. BEST PRACTICE GUIDANCE NOTES

A series of best practice guidance notes on living infrastructure design and construction are provided here for use by practitioners to help deliver the outcomes of this Plan.

BEST PRACTICE NOTE
10.1 BIODIVERSITY SENSITIVE URBAN DESIGN

Three critical elements of living infrastructure determine which plants, animals and other species can be supported in an urban landscape. We need to create enough space for species, be sure the surrounding environments are not too harsh, and help make food, shelter and resources available.

Addressing each of these three elements can help deliver urban landscapes that support high levels of biodiversity and improved quality of life for the people who live there.

1. PROVIDING SPACES WHERE BIODIVERSITY CAN LIVE AND MOVE

Open space allocation throughout dense urban areas will help provide more opportunity for vegetation to be planted, and for canopies to grow well. Wherever possible, adjust landscape designs to minimize the loss of existing vegetation and avoid the loss of native vegetation. New habitat, connections created at the ground and tree canopy levels between open spaces will provide additional habitat and better allow biodiverse species to move through the landscapes. Opportunities to provide additional spaces for biodiversity associated with the Metro Tunnel can be considered by all collaborators as the project progresses.

The next two elements will determine which plant and animal species are able to live in those newly created spaces.

2. SOFTENING THE IMPACT OF URBAN ENVIRONMENTS

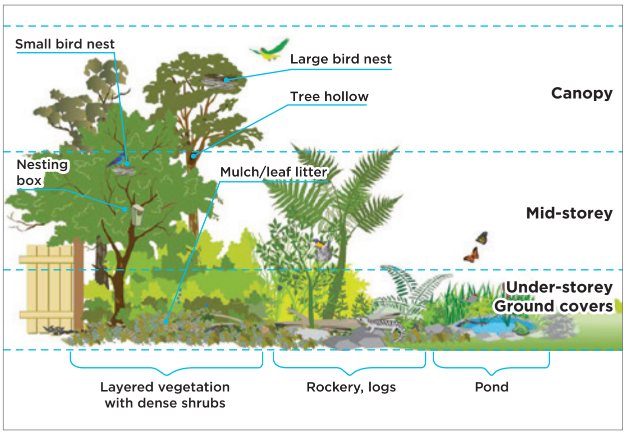
The urban heat island, altered water cycles, anthropogenic noise, artificial light at night and other human impacts can play a strong role in determining which plant and animal species are able to persist in an urban landscape.

By designing landscapes that reduce these harmful impacts, we are creating better environments for biodiversity, as well as creating more pleasant landscapes in which people can live, work and play.

For example, good hygiene practices for soil and equipment will reduce the spread of pests and diseases. Doubling the tree canopy and providing additional temporary vegetation during construction will contribute to reducing the urban heat island in these precincts; while maximising the capture of stormwater and reducing the use of potable water, will help reduce the magnitude of the altered water cycle.

This Best Practice Note also describes methods to reduce the impact of artificial light at night, which will also soften the impact of the urban environment to the benefit of people and biodiversity.

Diverse habitat garden



Source: Hunter's Hill Council, Wildlife Friendly Garden.

3. PROVIDING FOOD, SHELTER AND OTHER KEY HABITAT RESOURCES

For the plants living in urban areas, the critical habitat elements are suitable soils, availability of water and sun, and appropriate management actions to support their life cycle.

Plants may also rely on the presence of birds or insects for pollination or seed dispersal, earthworms and other invertebrates to return nutrients to the soil, and the presence of other species that help control their exposure to pests, pathogens and other forms of damage. For other groups of biodiversity, such as birds, insects, mammals, reptiles, frogs, fungi and fish, their presence in the landscape will be influenced by their ability to find suitable food, shelter and mates.

In a recent study investigating the features of urban landscapes that best support biodiversity, Beninde et al. (2015) found that the three most important elements were patch area, corridors and vegetation structure.

While patch area and corridors have been addressed in the earlier points, efforts to include a more diverse vertical vegetation structure that includes herbs, grasses and shrubs as well as trees are still emerging and there is a lot of room to improve our understanding of how these elements can be most effectively added to urban landscapes.

Typical cross section with planted nature strip (Illustration: Zoë Metherell)

Source: Moonee Valley City Council, Urban Ecology Park Scenario.

ACHIEVING COMPLEX VEGETATION STRUCTURE IN PLANTINGS

Complex vegetation structure includes the addition of a shrub layer or lower ground cover (taller grasses and low lying plants) which can fill in the gaps between the turf layer and the tree canopy.

Designs that allow for small areas of exposed soil or the accumulation of natural leaf litter can also help to provide additional habitat resources for animals such as native bees (which nest in areas of bare ground) and earthworms and other decomposers that help return the nutrients to the soil and reduce the reliance on artificial fertilizers.

The maximum benefit to biodiversity is most likely when there is a range of complex multi-story plantings. Complex vegetation structure can be delivered in various ways, including:

As multiple layers of vegetation within a planting area (for example, perennials, shrubs, trees, groundcovers), or as locations within a planting area that vary in terms of their vegetation structure (e.g. some plantings include shrubs and grasses with or without a tree canopy, other plantings include tall grasses or shrubs on their own).

Maintaining more complex vegetation structure plantings can have challenges, although these are likely to be drastically reduced as multi-story plantings become more frequently incorporated into urban areas. In the meantime, to ensure they are successful, it is highly recommended that the ultimate land manager of each site be consulted during the design phase regarding maintenance objectives for the site and their ability to deliver the required level of management. The final landscape designs and long-term operational maintenance plans should reflect and support this level of management.

PLANT SPECIES SELECTION

The choice of plants to include in a landscape needs to be informed by both their suitability to current environmental conditions, as well as conditions they are likely to encounter in the future, particularly for long-lived species such as trees. The configuration of plants will determine the amount of sunlight they are likely to receive, as well as the amount of sunlight likely to reach the pedestrian zone.

Plants that are performing well are less likely to attract negative comments from the public, and are also more likely to deliver their maximum ecosystem service potential within the expectations of a changing climate. Plant selection contributes strongly to the character of the neighbourhood, both as the most obvious visual component of biodiversity, as well as influencing the birds and other animals that may be present.

Balancing the various considerations during plant selection can be difficult, but there are several resources available to assist with this process.

The City of Melbourne uses its 2011 document entitled the Urban Forest Diversity Guidelines along with its Future Urban Forest 2016 report to guide street tree species selection for the municipality. These documents and any further updates should be referred to when selecting appropriate tree species for certain locations. Further to this, the City of Melbourne has conducted significant community engagement around street tree planting for each of its precincts to help guide their tree planting program. The results are presented in respective Precinct Plans and should be referred to when considering species selection in any of these precincts.

Heritage values play a key role in plant species selection in a small number of locations throughout the project. All areas to be planted within a heritage listed landscape must adhere to vegetation design guidelines and conservation management plans.

As the Green Building Council of Australia's Ecological Value Calculator is weighted towards the inclusion of native plants and native vegetation, the inclusion of indigenous species is highly recommended, with an emphasis on avoiding an over-reliance on mass plantings of a small number of species. There is an opportunity to integrate small to medium enterprise outcomes (MMRA Supply Chain Sustainability Target) in the sourcing of additional planting stock.

See inset box overleaf for additional information on plant species selection to best meet living infrastructure and urban design outcomes that most benefit inner Melbourne. The application of these guidelines will support the Environmental Performance Requirements including the need to ensure no invasive species are introduced via the works.

Tree supply must comply with Australian standards AS2303: Tree Stock for Landscape Use. All vegetation planting must meet the following requirements:

a. Purchased plant stock is to be sourced from nursery which can provide supporting evidence that it uses quality growing substrates and good hygiene practices (to reduce transfer of weeds and pests) to produce high quality planting stock.

b. Establishment of all plants, including drought-tolerant species, requires appropriate application of supplemental water for at least two growing seasons.

c. All planting areas to be maintained and weeds controlled through use of physical materials (e.g. mulch or other surface covers) during establishment.

d. Long-term maintenance plans to be provided as part of the landscape handover process.

NOVEL HABITATS

Some of the habitat features that birds, insects and other animals require may be scarce in urban landscapes.

In order to boost the availability of these key habitat features, artificial structures that mimic the role of a natural feature can be added to a landscape. For example, the density of large hollow bearing trees in urban landscapes can be quite low, so the addition of nest boxes that are designed to mimic hollows of different shapes and sizes can increase the diversity of hollow-nesting animal species in the landscape.

Many new examples of novel habitat resources are being incorporated into cities around the world, including floating habitat islands, bee hotels for beneficial insects, and public art sculptures that are designed as bat roosts or honeybee hives. Some of these novel habitat resources can be incorporated into the landscape by repurposing timber from trees removed during Metro Tunnel construction.

POLLINATOR PATHWAYS

Pollinator pathways designed to link habitat areas are a novel variation on the habitat corridor concepts. In urban environments, land allocation in a continuous corridor is difficult to achieve unless there is a waterway corridor or an older railway track or easement that remains undeveloped. A recent scientific study by Beninde et al. (2015) found that the presence of corridors in urban areas significantly improved the biodiversity recorded in those landscapes. A 'pollinator pathway' provides an urbanised variation to the habitat corridor by planting with design consideration to flying species that support pollination[67].

Pollinator pathways can include low lying flowering plants as well as trees that provide sources of nectar which can support the movement of pollinators (bees, beetles, birds, small possums) across the landscape. In the areas in and around Metro Tunnel construction sites, habitat links would be suitable near Domain Station (connecting Domain Parklands to Albert Park via the Boer War Memorial and Albert Rd) and at Parkville Station (running along Pelham St and connecting the large green spaces of Haymarket roundabout, University Square, Lincoln Square, Argyle Square and Carlton Gardens).

Bike paths associated with Metro Tunnel project also provide an opportunity to deliver additional biodiversity gain. This could include a 'bike lane-led' pollinator pathway which captures an important opportunity for the community to benefit from the multi-modal links connecting the people and biodiversity of inner Melbourne from the Western Suburbs of Footscray, through the CBD and into the Eastern Suburbs of South Yarra and beyond. For bike lane led pollinator pathways, bike lane design should incorporate habitat links however the layout must be best practice to ensure smooth and safe route for cyclists.

What's involved in a pollinator precinct assessment?

A pollinator precinct assessment requires the mapping of key ecological features within proximity to the site. The suggested scale is 400m radius around the site (or 200m radius for those sites with multiple pollinator options that are better shown in greater detail). The map is to show:

+ Location, area and habitat quality of nearby open space.
+ Location and species of street trees.
+ Location and habitat quality of nearby green roofs and walls.
+ Location and habitat quality of any nearby waterbodies.
+ Future greening plans of local government.
+ Key pollinator species to support in inner Melbourne include: European honeybee (*Apis melifera*), as well as 13 native bees and many beetles, butterflies, moths and other invertebrates[68], as well as bird and small mammals.

67 http://www.thenatureofcities.com/2016/01/20/can-cities-save-bees-how-can-urban-habitats-be-made-to-serve-pollinator-conservation-how-can-that-story-be-better-told/.
68 Mata L et al. (2016) The Little Things that Run the City – Insect ecology, biodiversity and conservation in the City of Melbourne. Report prepared for the City of Melbourne. https://luismataresearch.wordpress.com/the-little-things-that-run-the-city-final-report-15sep2016-highres/.

Planting for Urban Habitat – Additional Information

The following links describe specific habitat resources that can be incorporated into urban landscapes to support specific groups of animals. To date, there is a gap in the availability of design guidelines to support urban fauna opportunities however the following websites may help as starting point for habitat design considerations.

+ **General information** http://www.woaw.org.au/8andUnder/wild-living-guide-wildlife-gardens-victoria/.
+ **Birds** http://www.birdsinbackyards.net/Guidelines-Creating-Bird-Habitats.
+ **Microbats** http://ausbats.org.au/bat-fact-packs/4562894228.
+ **Frogs** https://www.melbournewater.com.au/getinvolved/protecttheenvironment/Documents/Frog-friendly-habitat-guide.pdf.
+ **Beneficial inserts** http://www.sgaonline.org.au/butterflies/ https://rirdc.infoservices.com.au/downloads/12-014.

  http://www.floraforfauna.com.au/downloads/Factsheet_on_Native_Bees.pdf.

Plant Species Selection – Additional Information

Additional information will help with plant species selection.

+ **Metro Tunnel Urban Design Strategy** http://metrotunnel.vic.gov.au/__data/assets/pdf_file/0016/51109/MMRP-Technical-Appendix-M-Urban-Design-Strategy.pdf.
+ **City of Melbourne Urban Forest Diversity Guidelines** https://www.melbourne.vic.gov.au/SiteCollectionDocuments/urban-forest-diversity-guidelines.pdf.
+ **City of Melbourne Future Urban Forest Report** http://www.nespurban.edu.au/publications-resources/research-reports/CAULRR02_CoMFutureUrbanForest_Nov2016.pdf.
+ **City of Melbourne Urban Forest Precinct Plans** http://www.melbourne.vic.gov.au/community/parks-open-spaces/urban-forest/pages/urban-forest-precinct-plans.aspx.
+ **Growing Green Guide 2014. Technical Guide, particularly Ch.2 Site Analysis; Ch.3 Design and Planning, Ch.8 Maintenance** http://www.growinggreenguide.org.
+ **Sustainable SITES Initiative v.2** http://www.sustainablesites.org.
+ **Heritage Victoria Landscape Guidelines** http://www.dtpli.vic.gov.au/__data/assets/pdf_file/0005/219236/HO_Guidelines_Landscape.pdf.
+ **Burnley Plant Guide** http://blog.le.unimelb.edu.au/2013/09/burnley-plant-guide-iphone-app/.

ARTIFICIAL LIGHT AT NIGHT

The brightness of Artificial Light at Night (ALAN) as seen from space has been used to map the density of people across the world for over a decade.

Upgrades to urban public lighting are currently applying LED technology due to greenhouse reductions and reduced costs to run. Evidence is now emerging that the bright white LED lights have adverse impacts on biodiversity (and on human sleep patterns).

Several simple principles have been identified to help minimize the impact of LED ALAN on the people and biodiversity living in our cities, while a more detailed evidence-base is being developed over the coming years. These principles can be incorporated into ALAN lighting plans, without compromising human safety or other obligations.

The following provide options to ensure minimal disruption to fauna and the public:

+ reducing the intensity of the lighting
+ reducing the blue area of the spectra
+ minimising glare and intrusion through the use of shields and other directional aids
+ keeping lights as close to the ground as possible
+ minimise number of lights and their hours of operation wherever possible, especially in natural areas.

BEST PRACTICE NOTE
10.2 SIZING TREE PITS FOR TREE HEALTH & STORMWATER MANAGEMENT

BACKGROUND

The Metro Tunnel Project will introduce two nine-kilometre rail tunnels from Kensington to South Yarra, tunnelling underneath Swanston Street with five new underground stations to be built at Arden, Parkville, CBD North, CBD South and Domain. The project is setting new benchmarks for sustainable outcomes including best practice sustainable soil management to support sustainable living and long-term management of urban environments.

BENEFITS OF ADEQUATELY SIZED STREET TREE PITS

Healthy trees thrive when they are provided with good soil conditions – with enough soil volume to provide the stability, nutrients and moisture they need. Trees planted in conventional street tree pits in urban environments often fail to reach their full potential or have a shortened lifespan due to many factors including:

1. The soil volume provided in a tree pit is too small.
2. The quality of soil is not compatible with the long-term needs of the tree(s).
3. The soil is not regularly replenished by rainwater as the tree pit may be sealed by concrete or bitumen reducing the potential for rainwater to infiltrate into the soil.

Street trees in the urban environment often grow in highly modified soil where the soil quality and quantity are sub-optimal. Street trees are competing for space with in-ground services and utilities, car parking, footpaths and other infrastructure.

Constrained urban trees in these conditions seek out moisture to survive, and can cause damage to surrounding pavements and utilities through uplift and root intrusion. Arborists, horticulturists and soil scientists have collaborated to create innovative solutions that allow tree roots to access sufficient volumes of soil without damaging infrastructure.

Current best practice utilises street tree pits which essentially are trenches, often under footpaths or roads, where soils are optimised, or otherwise modified for tree growth. The contiguous design of these trenches allows maximum soil volumes for trees and aims to create some separation from in-ground utilities (figure 1).

Figure 1. Installation of street tree pits

However, challenges can exist due to incompatibility with surrounding unmodified site soils: if the surrounding soil is a heavy, compacted soil with undesirable chemical properties, roots will not readily move into this soil. Smearing the sides of a trench, following excavation with a mechanical digger for example, may further reduce the capacity of roots to penetrate into site soils.

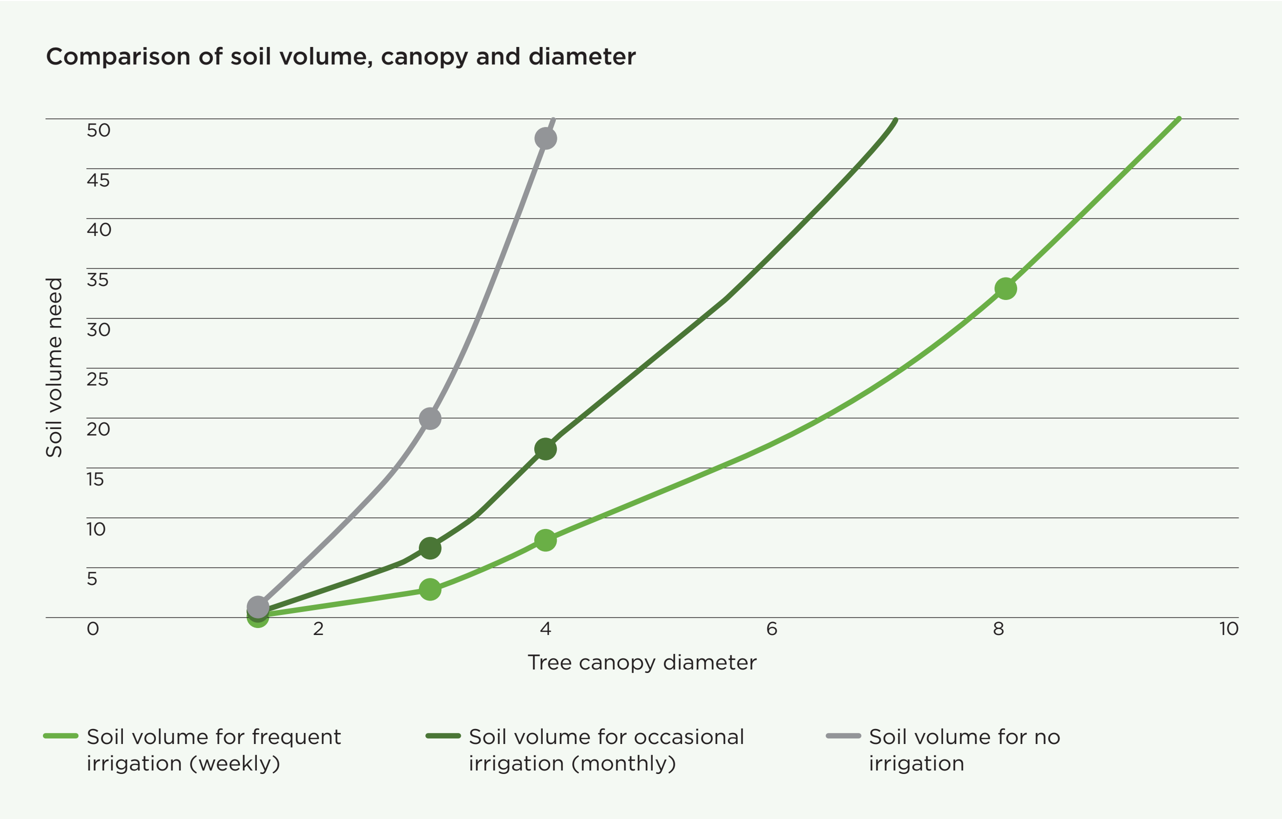
It is important to encourage root growth into the surrounding soil for a number of reasons, the main ones being access to larger reserves of soil moisture, and increased stability of trees from radial root development. To facilitate this, the site soil should be characterised to understand its properties and to evaluate its capacity to support good root growth. Once characterised a soil scientist can advise if amelioration is necessary. At a minimum, efforts are required to assist with 'keying in' of the imported soil and the site soil. This will involve 'roughing up' the side and the base of the trench to remove any smearing of trench faces and to increase surface area contact between the two soils.

Calculation of tree pit sizes is complicated by factors that determine the capacity of tree roots to spread into surrounding soils. Efforts described above aim to provide access by tree roots to deep supplies of water to increase tree survival through hot summers or prolonged drought.

Best practice street tree pit design aims to improve the resilience of streetscapes by maximising the capture of rainfall using the principles of water sensitive urban design and best practice stormwater management. Stormwater runoff from urban areas contributes to waterway pollution and can increase pressure on drainage systems resulting in flooding. Capturing this stormwater not only provides trees with essential water for life, it also captures nutrients that trees can use, entrains sediments that may otherwise end up in our waterways, and provides a pathway for detoxification of pollutants in the soil.

Studies of tree growth in containerised environments (such as tree plots) have shown that the ultimate growth and canopy diameter of a tree is related to both the soil volume and the frequency of access to water. Figure 2 below demonstrates this relationship, for example 20m^3 of soil can support a tree with a canopy in excess of 6m, if frequently irrigated, 4m if occasionally irrigated and only 2.5m if there is no irrigation.

Figure 2: Comparison of required soil volume to achieve the desired tree canopy in containerised environments under varying irrigation conditions in Melbourne (Hitchmough, 1994)



EXAMPLE

The **City of Hume** used specialised soil media and permeable paving to redesign a vegetated multi-modal street in **Tanderrum Way, Broadmeadows**. Construction was completed in 2010 with results from the growth of vegetation far exceeding initial expectations.

Details of the project can be found at:
https://www.clearwater.asn.au/user-data/case-studies/plans-designs/Tanderrum-Way_Print-version.pdf

Figure 3: The Tanderrum Way, Broadmeadows. Image: Hydroston.com.au

STEPS FOR APPLYING BEST PRACTICE TO SIZING OF STREET TREE PITS

Applying the following measures will ensure that the sizing of street tree pits are managed in a way that benefits water filtration, detoxifying pollutants, and supports healthy vegetation for shade and other amenity.

Step 1. Determine Local Soil Conditions and the Needs of Trees

Undertake an assessment of the local soil conditions and the needs of the identified trees for planting in the street tree pits. Soil assessment must be undertaken by a CPSS (Certified Professional Soil Scientist) accredited soil scientist.

Step 2. Determine Tree Pit Volume

Leake & Haege (2014) is one recommended methodology to calculate tree root volumes, and minimum tree pit volumes should be based on this (or equivalent industry recognised standards). The method of Urban (2008) states 'best practice soil volume for each tree must be approximately one third of projected canopy volume prepared to a depth of 1m'. Calculation of tree pit volumes should include an estimate of usable native soil adjacent to tree pits as provided by a soil scientist.

Step 3. Determine Tree Pit Supporting Structures

Where tree pits are covered by hard infrastructure such as footpaths or roads, consideration of supporting structures is required. Support structures are designed to carry the weight of the road or footpath while protecting the structure of the underlying soil.

There are two principal types of support structures – structural soils and strata vaults.

a) Structural soils are a blend of large (63mm) aggregate rock plus a fine textured soil.

b) Strata vaults are plastic structural units with large spaces for soil.

The large aggregate of the structural soil takes the weight of infrastructure and may be compacted to a high level. Roots grow in the soil held in spaces between the aggregates. Strata vaults are filled with soil and provide greater soil volumes per unit area compared to structural soils. The choice between structural soils or strata vault is usually dependent on the quality of surrounding soil to support plant growth, capacity to capture and store water, and cost.

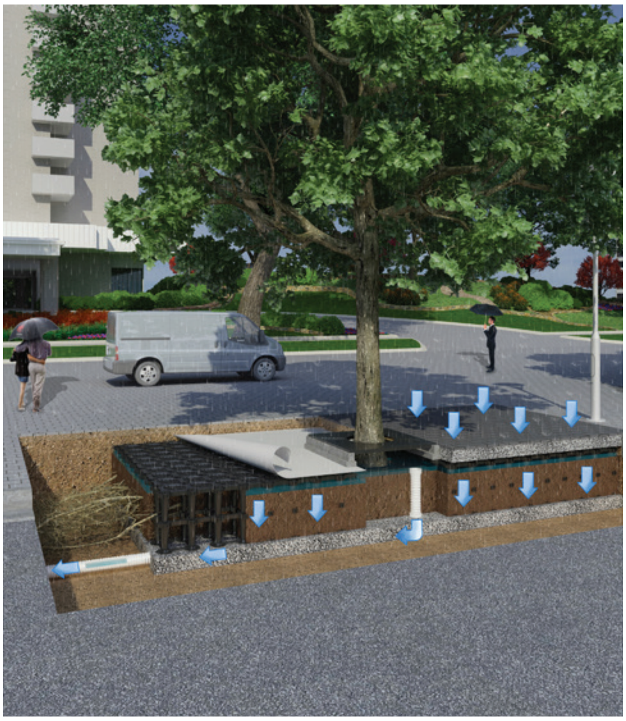
Step 4. Ensure design allows for adequate water

Passive irrigation is effective in helping trees to draw on local rainfall and thus help to protect waterways by slowing the flow of water into rivers and creeks when it rains and in capturing pollutants and other contaminants from hard surface runoff.

There are design solutions available which will support tree health (through use of good quality soils in sufficient volumes and access to passive irrigation) and will facilitate the achievement of best practice stormwater treatment requirements.

Soil selection for stormwater capture requires a balance between potentially competing properties – rapid infiltration and maximum water retention. For this reason, soil specification for stormwater capture and tree health requires assessment of local soil conditions and the needs of the trees.

Figure 4: Strata vaults are one option to support healthy trees



For healthy canopy, well designed supplementary irrigation will also be needed in times of water scarcity.

See *Metro Tunnel Best Practice Note – Passive Irrigation*.

BEST PRACTICE NOTE
10.3 PASSIVE IRRIGATION

BACKGROUND

The Metro Tunnel Project will introduce two nine-kilometre rail tunnels from Kensington to South Yarra, tunnelling underneath Swanston Street with five new underground stations to be built at Arden, Parkville, CBD North, CBD South and Domain. The project is setting new benchmarks for sustainable outcomes including best practice sustainable soil management to support sustainable living and long-term management of urban environments.

BENEFITS OF PASSIVE IRRIGATION

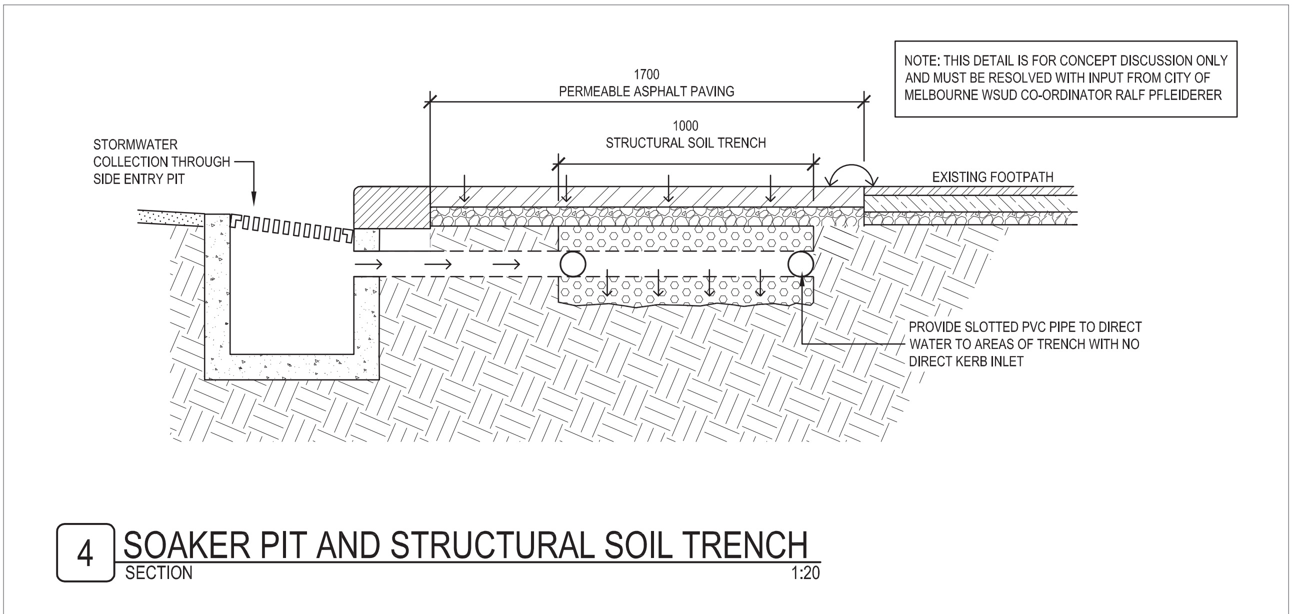
Stormwater is a free water resource for irrigation that can be harnessed to support Living Infrastructure in an urban environment. Street trees and gardens which are surrounded by paved surfaces are excellent opportunities for passive irrigation, by channeling stormwater from adjacent paved surfaces into the soil bed. As discussed in the 'Sizing Tree Pits for Tree Health and Stormwater Management' practice note, soil areas can also be used to benefit stormwater management and prevent drainage from damaging waterways.

Passive irrigation requires the direction of rainwater or stormwater runoff from an impervious (sealed or paved) catchment area that is greater than the garden area or tree plot itself, allowing the vegetation to benefit from a greater volume of water supply. To enable passive irrigation to occur effectively, a few design principles should be followed regarding inlet design, water distribution and overflows.

STEP 1. INLET DESIGN

The design of the inlet, that is the mechanism by which water is directed to the soil, requires careful consideration. The figures below provide some examples. Where there is a vegetated ground surface adjacent to a road a kerb inlet may be suitable, whereby a dip in a kerb allows water to enter the vegetated area or tree plot. However, this requires the soil surface to be sunken to the level of the road. This kind of design may not be suitable in some urban environments which experience high pedestrian traffic. Other examples allow the surface of a tree plot to be flush with the surrounding surface (either a soil surface or another permeable surface), and water to be provided from the road underground, entering via a stormwater pit or an inlet pipe.

Figure 1: Example cross-section for a tree trench system with passive irrigation used by City of Melbourne in Flinders Street. Image courtesy of City of Melbourne



STEP 2. WATER DISTRIBUTION

The second key design area for passive irrigation is the method of water distribution. Water from a single inlet point can lead to localised erosion and poor distribution of soil moisture if a distribution mechanism is not included. Where water is shed onto a garden or tree plot at surface level, it is important that the surface is flat and flush so water can distribute evenly, and that entry points are regularly cleared of debris. Where water is entering below ground, a perforated pipe surrounded by a sleeve of gravel can be used to distribute water across the soil profile.

Coordination will be needed during the design and construction of the tree pit and the soil layers to ensure water distribution is included and effective.

STEP 3. DESIGN OVERFLOW AND DRAINAGE

An important consideration of design is the provision of overflow and drainage points. While it is desirable to direct water to the soil area, it is also important that the growing area does not become water logged. Underdrainage below the soil area should be provided where water that isn't needed, can rejoin the drainage system.

Figure 2: Example of a passively irrigated tree pit in Little Collins Street and Burston Reserve, where stormwater from the road is channelled into the tree pit via a kerb inlet and stormwater pit (source: City of Melbourne)

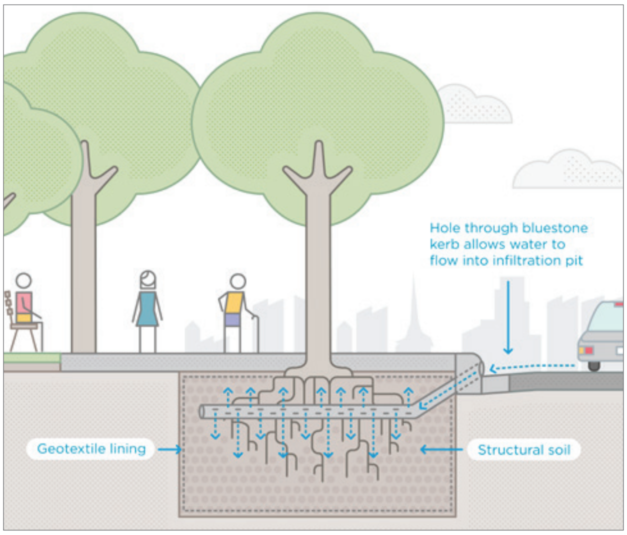


Figure 3: Example of a passively irrigated garden bed with surface inlets (source: City of Darebin)

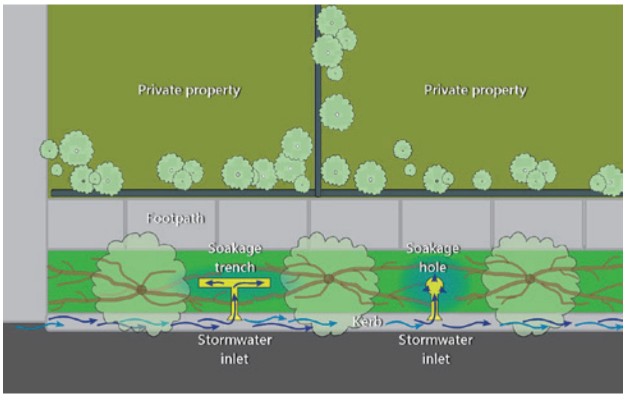
POSSIBLE PASSIVE IRRIGATION DESIGN SOLUTIONS

Two possible design solutions for stormwater capture are discussed below, along with advice on how to size tree pits in relation to access to stormwater. The practice note for 'Design details for passive irrigation' discusses possible inlet, water distribution and overflow arrangements.

Design Solution – Option 1

In areas where pedestrian activity is located only along the footpath, continuous soil volumes parallel to footpath and road can support healthy root growth and allow for passive irrigation through kerb inlets. These inlets allow water to filter through to a soakage trench. Roots growing laterally are provided with adequate water and nutrients and are therefore much less likely to grow towards private property, seeking water.

Figure 4: Aerial view of soaker trenches between trees in an avenue allowing roots to access water and soil volume, whilst also minimising damage to nearby property from tree roots (TreeNet, 2005)

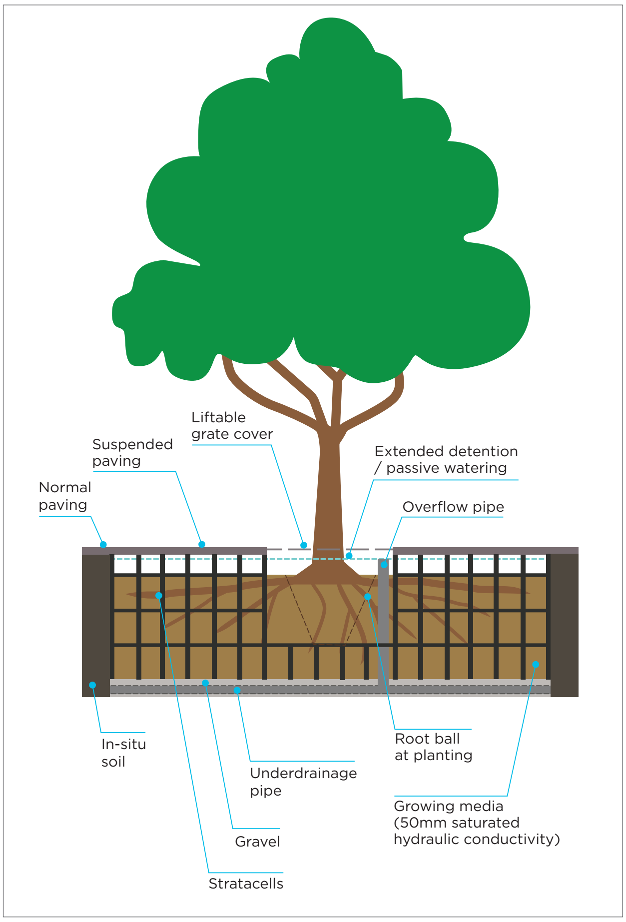


Design Solution – Option 2

By using a structural vault, the soil area available to a tree can be expanded underground, while still supporting other uses on the surface such as car parking, roadways and pedestrian pavements. This increased soil area also provides an opportunity to provide greater storage of water and use soil and vegetation to provide stormwater treatment. The diagram below shows an example design which can be replicated for an avenue of trees to provide a continuous root growing space underneath pavements.

It's important with all designs to ensure the provision of adequate overflow and drainage points such that incoming water is dispersed and scouring does not occur and that the growing area does not become water logged. As such, under drainage below the soil area should be provided where surplus water can rejoin the drainage system.

Figure 5: Example design of a tree plot designed for passive irrigation and stormwater treatment (E2Designlab, 2015)



STEP 4. SUPPORTING SUPPLEMENTARY IRRIGATION

In addition to reducing pressure on our stormwater system and local water bodies, it is critical to design irrigation to support the health of trees and vegetation in urban environments.

There are situations where supplementary watering, in addition to passive irrigation, is warranted to ensure that the tree and other vegetation is healthy and provides the desired services.

Examples of situations in which active irrigation may be required include low soil volumes, high water use species, strong tree development and growth stages, periods of drought, high evaporative demand conditions and tree establishment stage.

Successful tree establishment is critical for new plantings to become productive, in the landscape. Avoiding significant soil moisture stress is a key part of achieving successful tree establishment. Incorporation of temporary (i.e. 2-3 years) active irrigation, to support establishment should be considered in terms of having a secure water source available during this vulnerable stage of tree establishment.

The following is best practice for tree establishment:

a. Species selected appropriate to the site and purpose.

b. Quality nursery tree stock used.

c. Tree pit of adequate size.

d. Specified soil installed or soil amelioration carried out prior to planting

e. Transplanted by personnel skilled. in these practices.

f. Regular watering of tree (root ball) to initially support root growth and development.

For those situations, where active irrigation is beneficial or necessary to achieve the desired tree performance, the following outlines the factors support best practice in the planning and design of a tree irrigation system.

1. Distribute the water as widely as possible to the root system. Encouraging concentrated and confined root systems around irrigation delivery point areas increases vulnerability and diminishes the resilience of the tree.

2. Use mulch to cover irrigation components, however, select coarse mulch materials that allow precipitation (rainfall) to penetrate.

3. Select robust irrigation components and fittings. The urban street environment is harsh. System reliability is essential.

4. Small outlet orifices are prone to blockage, from within and external debris. Select non-clogging, flushing type of emitter devices.

5. Installation, including excavation, should be protective of tree root systems.

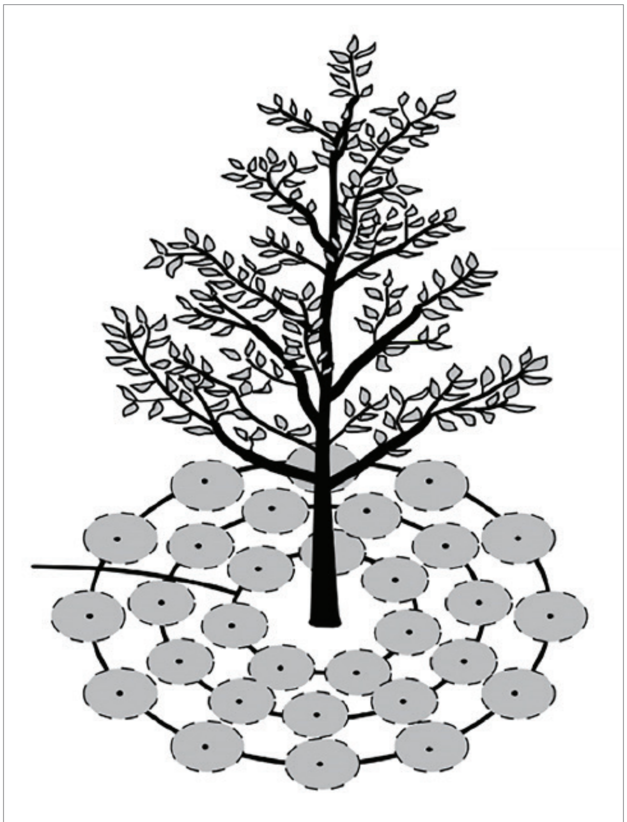
6. Irrigation system application rate should allow for the limited infiltration capacity compacted soils, so that runoff is prevented.

7. Water proactively, before the high evaporative demand conditions, rather than responding to physical signs of stress, such as leaf curl, leaf scorch and leaf drop.

8. Include dedicated water use metering to monitor and to schedule irrigation application.

9. Soil moisture monitoring is extremely valuable in understanding soil water status and water movement through the profile. The scheduling of irrigation can be programmed based on the actual water available to the tree.

Figure 6: The irrigation system design should take into account the species, age, soil and climate conditions of different trees. This figure shows a drip irrigation system applying water to the majority of the tree root zone Image: Best Practice Functional Open Space Guidelines



EXAMPLE

The City of Melbourne redesigned a section of **La Trobe Street** to include a new bicycle lane, passive irrigation and tree planting. The project has met several key outcomes for the City: stormwater reduction, increased canopy cover and an increase in safe bicycle routes for cyclists.

Details of the project can be found at:
http://urbanwater.melbourne.vic.gov.au/wp-content/uploads/2015/05/Urban-Water-La-Trobe-Street-Green-Bike-Lane.pdf

Figure 4: La Trobe Street, Melbourne's new bicycle path with passively irrigated new street trees

BEST PRACTICE NOTE
10.4 WILDLIFE TRANSITION IN CONSTRUCTION AREAS

CONSTRUCTION WORKS FOR METRO TUNNEL

The Metro Tunnel Project will introduce two nine-kilometre rail tunnels from Kensington to South Yarra tunnelling underneath Swanston Street with five new underground stations to be built at Arden, Parkville, CBD North, CBD South and Domain. The works will commence in 2017 and new train services will be operational by 2026.

Extensive analysis is being applied to ensure tree removal resulting from construction works (primarily at the abovementioned new station sites) can be avoided wherever possible, however the worst case scenario is the removal of up to 900 trees.

Several species of wildlife are known to inhabit the trees impacted by Metro Tunnel Project. These include microbats which shelter under the bark of trees and in small cracks and hollows, powerful owl females nesting in hollows from May to August, common brushtail possums which shelter in medium to large hollows, common ringtail possums which shelter in smaller hollows or dreys (stick nests), birds, reptiles and insects.

Each species has different habits and vulnerabilities. For example, the brushtail and ringtail possums are strongly territorial with respect to their den sites (hollows or dreys) and they are highly likely to burrow deeper into their hollows when disturbed. They tend not to flee elsewhere for safety.

Management measures need to be implemented to reduce disruption from construction and tree removal works, such as exposure, injury or mortality vehicle encounters when crossing roads, encounters with dogs and cats due to displacement and intraspecific competition with other possums over hollows or food resources.

The following guidelines are set out as steps that will minimise fatalities and harm to wildlife during the removal of trees and maximise the quality of feeding and sheltering habitat in the operation and legacy stage landscapes.

These guidelines primarily focus on support for terrestrial fauna species due to their restricted movement relative to flying birds and insects, and nimble reptiles.

WILDLIFE SURVEYS

Identify trees to be felled at least two weeks prior to clearing, assessing species, tree size, number and size of hollows and inhabited nests. All trees with hollows and inhabited nests should be clearly identified and distinguished from non-hollow-bearing trees.

Conduct additional surveys by suitably qualified ecologists or wildlife experts where necessary, to assess how many individuals of various species are likely to be impacted, and identify and document nests, dreys and hollows that are known or likely to be occupied by wildlife.

To best prepare for rehoming of fauna, surveys should be conducted at least two weeks prior to tree clearing. This will give an indication of the scale of fauna numbers that may need rehoming, with enough time for rehoming solutions to be prepared. Opportunistic stagwatching to directly count nocturnal animals, including use of spotlights could assist.

This information can then be used to apply a 1 for 1 replacement of existing hollows and nesting sites with suitably sized and orientated nestboxes customised for each animal species.

On the day of tree removal, hollows, and nests with eggs and new young, can be inspected to inform the tree-fellers and the wildlife spotter as to how many animals to expect and which hollows are occupied. Note that some hollows and nests may be too high or for other reasons not able to be inspected.

During the initial wildlife survey, the location and extent of hollows could be identified in trees slated for removal, with the potential for retaining these hollows for relocation in lieu of or in addition to nestboxes. This would be particularly efficient for hollows present in the limbs or branches of trees and would contribute to 1) respectfully finding new purposes for removed tree material; and 2) reducing the cost of nestbox construction.

STAGING THE REMOVAL OF TREES

Staged removal of trees where possible, will best avoid a concentrated impact of habitat loss and increase the chances of a successful transition process. The gradual removal of trees needs to be planned to minimise the likelihood that fauna rehome in a tree that will soon be removed.

Two stage removal by tree habitat status is recommended in helping transition fauna to new homes. For example, removing non-hollow-bearing trees on day one, and hollow-bearing trees on day two. This approach may disturb animals in hollows in adjacent non-hollow trees being removed and prompt them to seek alternate habitat in advance of fauna-bearing trees being removed. If only a small number of trees, for example less than ten and most are hollow-bearing, then there is no order of priority.

For larger areas, begin removal of trees towards the centre of the impacted area, to maintain greater habitat connectivity and options for wildlife to voluntarily relocate further away from the impacted areas.

PREPARING FOR THE RELOCATION OF FAUNA

Relocating of fauna requires consideration of whether future habitat options are ecologically viable. This means understanding the likely ecological impacts of introducing new fauna into a new tree or habitat.

Given this is an emerging field of practice, quite often this impact will not be known and this will prevent some rehoming activities from being undertaken. It is hoped that increasing the best practice for fauna relocation in future years will help prompt more studies to help progressively grown this knowledge.

Planting known food sources in advance at the non-impacted relocation sites will also help to reduce the pressures of intraspecific competition. This will only be applicable if food sources are planted in advance of tree removal to enable adequate growth.

Between 3 and 7 days prior to tree removal, place suitably sized nestboxes in non-impacted trees in adjacent areas. These trees will be release sites for captured brushtail possums, and therefore must meet the requirements of the [existing wildlife removal and relocation] standards. Ideally, one next box should be placed for each animal that will be relocated.

One way flaps can be fitted to known nesting hollows after nest boxes are installed and before the clearing commences. This will facilitate some fauna rehoming prior the main tree removal event. It is noted that the efficacy of one-way flaps in trees is still being explored, and it may be more effective to undertake two stage clearing. There are valuable applied learning research opportunities on this topic.

Due to the large numbers of trees that are likely to be impacted at the different construction zones, it might be worthwhile investigating alternative methods for encouraging animals to voluntarily relocate. The use of sound in the relocation of Grey-headed Flying Foxes from botanic gardens in Melbourne and Sydney is an excellent example of how large numbers of individuals can be relocated based on an understanding of the species ecology and behaviour. Removing non-hollow-bearing trees a few days prior to clearing is one method that can encourage animals to move out of landscapes, and has been used effectively in other projects.

Nest-box design tailored to species

Different sized animals require nestboxes with different sized internal spaces, differently sized and located entry holes, and placement on trees with respect to tree limbs and other factors. A good guide to constructing suitable nestboxes can be found at: http://faunature.com.au/nest-boxes-for-wildlife-a-practical-guide.

Placement of nestboxes is also a critical element determining whether an animal will take up occupancy. Nestboxes should not be placed on north or west facing sides of trees as they will not have sufficient thermal protection during the hot periods of the day. Care should also be taken to locate them where they are least likely to be affected by artificial light at night impacts.

TREE REMOVAL DAY

On the day of tree removal, arrange for wildlife spotter and rescue services to be present to capture and relocate affected animals. All activities must comply with the Wildlife Act 1975 and will require permits which must be arranged in advance.

All hollows within felled trees should be inspected and any resident animals removed and relocated. Animals that flee their hollow before or during tree felling should also be captured with a net and rehomed, however a judgement call is required if it is likely the animal can find itself a new home with less stress than that which would be caused by the capture process.

Specific requirements related to wildlife relocation must be observed and complied with on the day.

Rescued animals should be released directly into a nest box. The entrance to the nest box should be stuffed with a rag to prevent them fleeing during the day, to be removed at dusk.

If a large number of trees are to be cleared, it may be necessary to hold animals in cages during the day and release at dusk that night. The animals need to be supported with food and water while in cages during that day.

If female with back young or large pouch young is rescued they should be kept in cage during the day, to prevent the likelihood of the mother dropping the back young / large pouch young, and gently released after dusk that evening. Release process is to secure the door in the open position, place cloth over entrance and monitor the cage from a distance until the possum exits of its own accord.

Transferring animals to trees that are on the same side of a road as the trees being cleared may help reduce the number of vehicle strikes as the animals may be less likely to attempt to cross the road to more familiar territories.

Injured animals should be taken to vet for assessment, or a wildlife shelter for rehabilitation. It is best for vets and wildlife carers to be forewarned of the clearing activity to enable them to prepare care or euthanasia facilities as required.

There is a limited understanding of how fauna adjust to these relocation events. This project represents an applied learning legacy opportunity by partnering with researchers to study and track how affected animals respond to a disturbance of this kind.

Further information

https://www.wildlife.vic.gov.au/managing-wildlife/wildlife-management-and-control-authorisations

https://www.wildlife.vic.gov.au/managing-wildlife/translocation-of-wildlife

https://www.wildlife.vic.gov.au/managing-wildlife/possums

http://www.birdsinbackyards.net/places

http://www.sgaonline.org.au/artificial-tree-hollows-for-animal-habitat

BEST PRACTICE NOTE
10.5 LOCATING TREES FOR LIVING INFRASTRUCTURE OUTCOMES

The Metro Tunnel Project will include extensive tree planting. This Best Practice Note provides decision considerations to help determine the location of tree planting that will support living infrastructure.

Finding suitable locations in urban areas to plant trees that will grow to achieve a large healthy canopy requires the consideration of many factors. For example:

+ Is there available space above ground, below ground and at street level to minimise infrastructure and functional conflicts?
+ Do the local neighbours and the wider community want more trees? If so, what type?
+ Do the trees need to fit into an existing boulevard or patterned planting scheme?
+ Will the tree fit in with the existing layout, scale and character of a streetscape?
+ Are there streetscape, heritage and built form plans that will impact tree locations?
+ Is there suitable soil density, soil moisture and soil health to support a tree?
+ Is there adequate water available to support this tree in the long term?

Most of the trees in our streets and parks are managed by local government and the decisions for their location and species selection are made based on their expertise and community consultation.

In addition to the above criteria, it is increasingly important to also consider how our urban trees contribute to broader sustainability and public health goals for our cities. These goals are generally directed by the policy priorities of local and State government.

Tree planting will be done in all seven Metro Tunnel Project precincts spanning across the City of Melbourne, City of Port Phillip and City of Stonnington. Two advanced replacement trees will be planted for every tree that needs to be removed to support tree canopy. Replacement trees will be located as close as possible to the location of removed trees in accordance with consultation from local government and the University of Melbourne.

The Metro Tunnel Project is committed to more than the replacement of trees lost during construction. Tree (and vegetation) planting is required to contribute to the following Metro Tunnel sustainability targets:

+ Double tree canopy cover by 2040 compared to base case through the reinstatement of lost trees, planting of new trees, and the creation of improved growing conditions.
+ Total amount of vegetated surface permanently gained post construction must be greater than total amount of vegetated surface area permanently lost.
+ At least 25% of new and reinstated planting areas must consist of diverse, multi-story plantings for biodiversity.
+ Use rainwater and/or stormwater to provide passive irrigation to all tree plots and vegetated areas to support soil moisture needs.

To help meet these targets, the Metro Tunnel is able to support some tree planting beyond the construction precinct zones of the project area. This will create an additional community and environmental legacy outcome, and can be delivered in partnership with local government and other potential land managers that are able to support the short and long term commitment of additional trees and landscaping.

The location of the additional trees will ultimately be guided by the policies and expertise of the ongoing land manager. These additional trees do need to maximise their potential for supporting living infrastructure outcomes as much as possible with the budget available.

To guide the decision making process to best support the multiple objectives of the Living Infrastructure Plan, the following tree location hierarchy has been developed.

TREE CANOPY SUSTAINABILITY TARGET BASE CASE AND TARGET METHODOLOGY

Objective

One of the project objectives for the Metro Tunnel Project is 'to protect and enhance vegetation, functioning of ecosystems and maintain biological diversity'.

This objective is supported by Metro Tunnel Sustainability Targets including: 'Double tree canopy cover by 2040 compared to the base case through the reinstatement of lost trees, planting of new trees, and the creation of improved growing conditions'.

Tree canopy cover relates to the Metro Tunnel Project area.

Methodology for establishing tree canopy base case

'Tree Canopy Base Case' is defined as the square metreage of tree canopy that will be lost due to tree removal to make way for the Metro Tunnel Project and will be calculated upon confirmation of the final design for the Metro Tunnel (as this will be the earliest point at which tree impacts will be confirmed).

The base case methodology will apply the following principles:

+ The canopy will be expressed in m^2 and will encompass the area of tree canopy to be removed.
+ The canopy of each tree removed will be based on existing City of Melbourne tree canopy data, canopy mapping using aerial imagery undertaken for City of Phillip, City of Stonnington and University of Melbourne as of 2016. It is not based on the potential canopy of that tree.
+ The canopy base case will include all existing trees, including juveniles. The only exception is for declared noxious weeds.

Early canopy calculations to predict tree canopy outcomes applied two different methodologies:

+ Desktop assessment using recent, high quality aerial photography; and
+ Field assessment where qualified arborists in the field measured the extent of tree canopies.

The two different assessment methodologies were found to provide very similar results in determining that planting two trees for each tree removed for the Metro Tunnel Project, will generally meet the objective to meet the 'double canopy by 2040 target.'

Tree Location Hierarchy for Living Infrastructure Outcomes

Please note, this hierarchy is to provide early guidance on how a tree location can help provide living infrastructure benefits. This is a starting point for considering tree locations and needs to be followed by critical tree viability issues as guided by arborists and land managers.

Methodology for determining additional tree planting

The 2040 tree canopy area will be modelled on species selection, growth rates and growing conditions such as allocated soil volume and specification, canopy space and access to soil moisture, in line with Metro Tunnel Project engineering and landscape design.

Due to spatial site constraints, it is not expected that the doubling of canopy will be fully achieved within the designated Metro Tunnel Project area and additional tree planting will occur outside the Project Area, in line with the Living Infrastructure Plan hierarchy as follows.

Replacement tree will be planted with advanced tree stock as close as possible to the location of any removed tree. If that cannot be undertaken, the replacement tree will be included in the alternative locations listed for additional trees as set out below.

Additional trees will be planted in the following hierarchy:

1. Located as close as possible to the Metro Tunnel Project area in the following order of consideration:
   + within the Metro Tunnel Project area
   + above, along and adjacent to the Metro Tunnel alignment
   + within the municipalities of Stonnington, Port Phillip, and Melbourne.
2. Located on land that maximises the public benefit of the tree for the long term (and there is demonstrated capacity of the land manager to maintain tree health and risk management). The order of consideration is:
   + local government managed land (Stonnington, Port Phillip, and Melbourne)
   + University of Melbourne Parkville campus
   + other government and institutional land used and accessed by the public
   + other land whereby the benefit of the tree is enjoyed in the public realm (e.g. commercial land with tree planting along its fenceline providing shade for footpath).
3. Located where the tree can best address the local community and environment benefits. The order of consideration includes opportunities to:
   + Reduce the impact of thermal hotspots with a priority for improving pedestrian and cycling comfort.
   + Increase the canopy cover in the precincts with lower than average tree canopy coverage (Western Portal, Arden, CBD North, CBD South, Parkville).
   + Optimise opportunities to capture, treat and slow the flow of stormwater.
   + Benefit biodiversity by helping fill a habitat gap for fauna, birds and other pollinators.

These locations will be chosen in consultation with each of the tree asset owner stakeholders.

BEST PRACTICE NOTE
10.6 GREEN WALLS FOR CONSTRUCTION SITES

CONSTRUCTION WORKS FOR METRO TUNNEL

The Metro Tunnel Project will introduce two nine-kilometre rail tunnels from Kensington to South Yarra tunnelling underneath Swanston Street with five new underground stations to be built at Arden, Parkville, CBD North, CBD South and Domain. The works will commence in 2017 with and the new train service will be operational by 2026.

Metro Tunnel is committed to sustainability leadership as set out in its Sustainability Targets and Draft Living Infrastructure Plan. These commitments will influence outcomes at every level of the project.

Construction activities will take years and cause considerable disruption to inner Melbourne, its local businesses, residents and visitors. Many design and management strategies are applied to reduce the impact of these construction works.

One of these mitigation strategies is the application of temporary 'green walls' fixed to site hoardings around construction sites.

Green Walls for Construction Sites

'Green wall' refers to the plants, and also for any supporting systems suitable for sustaining vegetated walls. Green walls are also designed to support placemaking elements such as artwork, seating viewing portals, community information walls and vegetation to support community and communication.

Green walls at construction sites respect the core function of the hoarding is to secure the construction site to provide safety for workers within the site, and for the public outside the site.

Van Gogh Green Wall, National Gallery, Trafalgar Square.

Benefits of Green Walls

As set out in the Metro Tunnel's Living Infrastructure Plan, the benefits of green vegetated walls include:

+ Maintaining local amenity values in the site and providing the public with a "green dose" of vegetation[69].
+ Filtering airborne particulates[70] and gaseous pollutants[71].
+ Cooling benefits through shading and evapotranspiration which can benefit both the construction site and the public realm[72].
+ Reduced noise impacts due to physical attenuation.
+ Provision of additional habitat for biodiversity, including pollinators and other beneficial insects.

69 Growing Green Guide (2014) Section 2. Evidence-Based benefits of green roofs, walls and facades.
70 Litschke, T. and Kuttler, W., 2008. On the reduction of urban particle concentration by vegetation–a review. Meteorologische Zeitschrift, 17(3), pp.229-240.
71 Janhäll, S., 2015. Review on urban vegetation and particle air pollution–Deposition and dispersion. Atmospheric Environment, 105, pp.130-137.
72 Growing Green Guide (2014) Section 2. Evidence-Based benefits of green roofs, walls and facades.

Greater investment in hoardings as a city feature via a green wall approach can generate project management benefits including greater community patience with a construction project.

Green walls for construction sites will contribute to the achievement of the Metro Tunnel Sustainability Targets in particular commitments for Urban Ecology, Water and Excellence.

The following guidelines are set to maximise the environmental, social and economic benefits that can be generated by investing, designing and maintaining vegetated hoardings.

STEPS FOR APPLYING LEADING PRACTICE FOR GREEN WALLS AT CONSTRUCTION SITES

Step 1: Hoarding Location

Applying the following best practice measures will ensure that hoardings are placed in a way that benefits the local precinct by providing comfort, convenience, and accessibility.

+ Conduct a survey of existing pedestrian flows to understand the destination and accessibility priorities around the site. This includes priority access needs for adjacent businesses. This will inform priority walking routes for the hoarding placement to support.
+ Conduct a survey of existing cycling needs, public transport, car share and freight needs around the site. Predict variations to these needs that will arise from the construction projects. This understanding of competing land use needs will inform hoarding placement, including necessary prioritising of pedestrians over non-critical car travel and parking.
+ Conduct a survey of informal community lingering and gathering patterns within view of the site. Predict variations to these needs that will arise from the construction projects. This understanding of competing land use needs will inform hoarding placement to support public seating or gathering.
+ Conduct a microclimate assessment of areas surrounding the site including morning sun, afternoon shade, wind, existing vegetation and water features[73]. This information will inform hoarding placement to maximise human comfort and public seating or gathering points.
+ Conduct a water assessment of site and surrounds to identify stormwater pits, and options for delivery of irrigation water.
+ Conduct a pollinator assessment (see Best Practice Note 10.1. Biodiversity Sensitive Urban Design) of precinct to determine range and availability of existing plants that can support beneficial insects, birds, bees, and bats. This information will support vegetated hoarding placement to support pollinator opportunities.

Green wall, King's Cross, London.

Step 2: Green Wall Design for Construction Sites

After working out where best to place the hoardings, apply the following measures to design them in a way that provides community and ecosystem service benefits.

+ **Structural engineering design** and certification for the hoardings must meet Australian Standard AS 4687—2007 for Temporary Fencing and Hoardings. This will ensure hoardings safely provide for the weight of any attached vegetation and supporting systems as well as relative site specific wind loading etc.
+ **To maximise air quality benefits**, green walls are best located between people and key dust generation, machinery and vehicle emission areas. Vegetation will intercept particles, absorb some pollutants, and alter breeze patterns[74] to improve local air quality. Plant selection aimed at increasing deposition of airborne particulates involves plants with hairs, and large leaf surface area.

73 Brown RD (2010) Design With Microclimate. The Secret to Comfortable Outdoor Space. Island Press.
74 Beckett, K.P., Freer-Smith, P.H., Taylor, G., 2000. Particulate pollution capture by urban trees: effect of species and windspeed. Glob. Change Biol. 6, 995e1003.

+ **To maximise climate resilience**, it is important that green wall design and plant selection be undertaken to generate local microclimate benefits including the reduction of urban heat island impact through dense vegetation, shade (where possible) and reduced thermal heat creation by limiting direct solar radiation to dark hard surfaces. The species needed to support this cooler urban area will be dependent on irrigation, and it is essential that this irrigation system is rigorous for these plants to survive heatwaves and dry spells. Local stewardship by interested nearby businesses and construction staff can help alert maintenance crews when there is a need for plant care.
+ **To maximise water conservation**, a system that uses wicking or soil-moisture responsive irrigation is preferred to ensure water use is driven by plant culture, ensuring minimal waste. Irrigation of green walls using recycled water, or diverted from a downpipe into a temporary raingarden will save potable water. Whilst it sounds contradictory, low-water using plants are generally not recommended for green walls, as healthy dense foliage is needed to maximise air, biodiversity and human thermal comfort.
+ **To maximise the health of nearby water bodies**, it is important that raingardens are located between all hard and soft landscape features and the legal point of discharge into the stormwater systems. Raingardens capture stormwater runoff containing 'air pollution particles' that fall with rain and are washed from hard surfaces during rain events and excess nutrient from Green walls. This prevents pollution dispersal into waterbodies. Alternatively, a suitable sump collection point can be used to capture excess runoff water, which can be pumped back up for reuse[75].
+ **To maximise wind protection for plants and then for people**, it is critical to apply careful selection of plants, by locating more vigorous plants along the exposed edges of the wall to provide protection for plants in other areas within the wall[76].
+ **To maximise biodiversity and pollinator opportunities**, ensure plant density covering 100% of hoarding areas allowed within AS 4687—2007 for Temporary Fencing and Hoarding, and choose plant species according to the needs identified in the 'pollinator precinct assessment'. For example, tubular flowers require pollinators with long tongues or curved bills, whereas flowers with a shallow cup (e.g. Myrtaceae) can be used by an alternative group of pollinators. Selecting plants with extended or complementary flowering periods will ensure the resources are available to pollinators year round.
+ **To maximise environmental benefits** generated by the green wall, it is important to ensure components are durable and modular for future reuse, and that materials apply industry leading levels of recycled and recyclable content.
+ **To maximise suitability of green wall system** or bespoke designed system, it must meet site specific orientation needs. For example, direct sun on a west facing wall on Swanston Street or Collins Street or south facing wall on Flinders Lane will be impacted by SW prevailing wind exposure in winter and shading and lower light. Selection of the system will depend on the soil media required to sustain plants. This will impact the ultimate weight on the hoarding to be certified by the Structural Engineer to meet Australian standards.
+ **To maximise the safe placement of the vegetated system** it is necessary to apply the Australian Standard AS 4687—2007 for Temporary Fencing and Hoardings. Issues to consider are reducing the climbability likelihood by the public to prevent the likelihood of falling and entering the site. To address this, the designer will consider solutions such as the design height from the surrounding natural ground where a system can begin and the design height from the top of the hoarding.

75 http://www.growinggreenguide.org/technical-guide/construction-and-installation/green-walls/.
76 Growing Green Guide 2014. http://www.growinggreenguide.org/technical-guide/design-and-planning/plant-selection/.

Green Green Screen, Tokyo.

Green walls with rock seating Hougang Primary School.

Step 3: Vegetation Management

Green walls require ongoing maintenance and monitoring to ensure ongoing healthy growth. The following standards will maximise their long term health.

+ Irrigation disruptions are a critical risk for green wall survival. Regular maintenance must be conducted, and online monitoring of irrigation is recommended to identify any malfunctions early. Local stewardship by interested nearby businesses and construction staff can help alert maintenance crews when there is a need for plant care due to irrigation problems or other significant disruptions.
+ Establish maintenance standards to ensure ongoing plant care, plant renewal (as needed), irrigation, and pruning. Be clear about this requirement in all tender specifications and contracts to be sure to account for the cost of maintenance.
+ Plants that are serving a primary air pollution removal function will need regular maintenance to remove buildup of dust and emissions on leaf surface (this is especially critical in times of low rainfall).
+ Plant pest and diseases, vandalism and seasonally fluctuating weather exposure can cause unplanned detrimental impact to some species. Contingency provision in design, construction and maintenance budgets for replacement of failed species must be considered.

Step 4: Monitoring

While there is a growing body of evidence to indicate that vegetation installations such as green vegetated hoardings will deliver benefits for people and biodiversity, the degree of impact is still relatively unknown.

Monitoring the biodiversity visiting the green vegetated hoardings can help demonstrate the value of changing the business as usual approach and provide a unique story around positive contributions to public benefit even during construction.

The Living Infrastructure Plan identifies several models for monitoring the social and ecological benefits as part of the Applied Learning Legacy. These models include developing partnerships with researchers who can assist with the monitoring activities and extend the knowledge sharing outcomes. These projects can be short-term and project focused, or can be approached as part of a larger partnership with the option to value-add through competitive research grants such as the Australian Research Council's Linkage Project funding scheme.

BEST PRACTICE NOTE
10.7 SOILS FOR URBAN LANDSCAPES

BACKGROUND

The Metro Tunnel Project will introduce two nine-kilometre rail tunnels from Kensington to South Yarra, tunnelling underneath Swanston Street with five new underground stations to be built at Arden, Parkville, CBD North, CBD South and Domain. The project is setting new benchmarks for sustainable outcomes including best practice sustainable soil management to support sustainable living and long-term management of urban environments.

Please note, this Best Practice Note refers to landscaping works.

BENEFITS OF HEALTHY SOILS

Appreciation of the importance of soils as a founding element of the biophysical environment is growing. What was once dug up, buried, drilled, ploughed and compacted is slowly being recognised for what it is – the ultimate source of all terrestrial life.

A healthy topsoil, which typically consists of the top 20 or 30 cms of soil, has more organisms per $10cm^2$ than the total number of humans that have existed on earth. However, the practicalities of city living have meant that soils have been used as a medium to support buildings and roads rather than valued as living realms.

If we think of soil in the urban environment, we probably think of public parks, tall trees and garden beds. However, most soils in the urban environment have been subject to:

+ sealing with bitumen and concrete,
+ excavation for trenching,
+ inverting of soil profiles with topsoils returned and subsequently mixed with subsoils,
+ high levels of compaction, and
+ contamination with building material or runoff from city streets.

ISSUES FOR HEALTHY SOILS

Urban impacts on soils result in:

+ interruption of carbon and nutrient cycling,
+ reduced water ingress,
+ reduced air movement into and out of soils, and
+ reduced biological function as a result of impaired energy flows from declining carbon levels.

This often means that trees and other vegetation growing in urban environments are heavily stressed leading to pest and disease pressure and a slow decline often ending in death.

Understanding the soil as a living realm allows a more sophisticated approach to its management. This principally involves recognition of the soil as a complex ecosystem and the need to manage it using ecological principles. We recognise that soil is easily damaged and that soil communities can take many years to recover ecological function following disturbance[77]. This impacts on the quality of ecosystem services that soils provide to humans, examples of which include:

+ water filtration,
+ detoxifying pollutants,
+ supporting healthy vegetation for shade, and other amenity.

77 Elly Morriën et al, Soil networks become more connected and take up more carbon as nature restoration progresses, *Nature Communications* (2017). DOI: 10.1038/NCOMMS14349.

DESIGN PROCESS AND THE SOIL APPROACH

The overwhelming focus of the Metro Rail Tunnel Project is infrastructure development. Soils are principally assessed from a geotechnical viewpoint, i.e. what will be the risks to the planned infrastructure and how are they best managed? However, once the infrastructure is in place, the living infrastructure assumes greater prominence as the built structures will be softened and made more amenable by the shade of trees, the colour of in-fill plantings or the drama of a green wall.

The soil conditions across a site may vary widely with potentially major implications for a landscape design. Understanding urban soils allows for a greater likelihood of successful living infrastructure outcomes.

The first step in this process is analysing on-site soil resources. An appreciation of soil quantity and quality is essential prior to completion, or at a minimum, implementation of a design. Too often soil scientists have seen beautifully designed landscape plantings fail because of a complete incompatibility between design elements and soil conditions. Soil analysis provides empirical data upon which sound decisions are made. Good data removes guess-work, avoids waste, and targets investment in support of design outcomes.

The second step is to articulate the 'soil approach'. This is a simple concept that ensures design outcomes are optimised by specifying exactly what soil properties are required to sustain the intended design. This will guide planning around the purchase of new soil, improve existing soil or elements of both.

The third step in this process involves finalising the landscape objectives based on knowledge, understanding and appropriate management of soils for the project.

SPECIFYING SOILS FOR URBAN DEVELOPMENT

Our historical view of the role of soil in the urban environment has been to support the built environment and to provide the means for trees, shrubs and grasses to grow.

Apart from a growing understanding of the ecosystem services provided from soils, we now recognise that 'soils ain't soils'. The development of urban soil science has seen the development of soil specifications where soil scientists can prescribe specific properties to optimise the performance of landscape designs. In the past, plants were put into the ground and they either grew or didn't grow. Now, the landscape or urban designer can select soil properties for a native garden, a xerophytic (low water use) garden, or a garden integrated with a stormwater capture and purification system.

As an example, the designers of the Barangaroo Headland Park in Sydney wanted to re-create a Sydney sandstone flora ecosystem in the middle of the city (figure 1). There was no commercially available soil to suit the needs of this low pH and very low nutrient ecosystem so a site specific soil specification was developed following detailed research into the properties of native Sydney sandstone flora soils. The soil was manufactured on site by crushing the very large quantities of sandstone that were excavated from the commercial end of the site, blending it with compost and adding selected plant nutrients.

Figure 1: Barangaroo Headland Park, Sydney.

The new role of soil in the urban environment is to support design aspirations for the creation of spaces that reference the history of an area, commemorate periods of historical significance, provide amenity in the form of islands of refuge from the heat of modern cities, or to beautify spaces such as walls, roofs or hoardings as discussed in *Metro Tunnel Best Practice Note – Green Walls for Construction Sites.*

Expanded design possibilities in the urban environment have been made possible by the work of soil scientists in developing designer soils for abovementioned uses. Included is the rapid development of green walls and green roofs while interior landscaping is a more prominent feature of modern offices and apartment blocks.

Figure 3: Victorian Comprehensive Cancer Centre, Melbourne.

The Victorian Comprehensive Cancer Centre showcases the success of design lightweight soil media in its landscaping.

Designer soils are becoming accepted as a normal part of landscape planning in the urban environment in view of the flexibility that sophisticated soil specification allows.

This *Metro Tunnel Best Practice Note – Soils in Urban Landscapes* is supported by range of soil specifications including, as relevant, soil specifications, as necessary to support growing media for street tree pits (including pits with structural soils and stormwater harvesting), garden areas, podium plantings, native planting, amenity turf, green walls and green roofs.

LIVING SOILS CAN COMBAT CLIMATE CHANGE

Matching soils with the needs of plants and overall landscape designs also seeks to address the underlying ecological requirements of the soil / plant system. Research has shown the immense complexity of soil / plant interactions in the form of plants signalling their nutritional or defence needs to the soil's microbiome, and the soil organisms' responding with preferential delivery of nutrients to the plant, or the mobilisation of organisms antagonistic to a plant pathogen[78]. There is also ample evidence of the existence of immune systems in plants where infection, or a threatened infection, will initiate the evolution of antimicrobial compounds[79]. When these aspects of soil function are supported, plant health and longevity are greatly improved.

An important aspect of soil specification for urban developments is building resilience to climate change. With anticipated rising temperatures becoming a reality, our living infrastructure will come under greater threats in urban heat islands. There are two main options to manage this threat: select, or breed plants with superior heat tolerance; and maximise rooting volumes and depth, and water holding capacity of soils. Soil scientists prescribe organic amendment of soils to enhance water holding capacity, and to the extent possible will encourage designers to allow access by plant roots to surrounding native soils.

Specification of urban soils aims to enhance soil chemical, physical and biological properties so that ecological function is optimised. Understanding that all nutrients cycle through various forms requires designers to facilitate natural cycles as much as possible. As an example, trees growing in natural environments shed leaves and bark over 12 month cycles. Those materials are rich in plant nutrients, particularly potassium which is an essential element for plant health. When trees are growing under bitumen or concrete, the return to the soil of organic matter and the nutrients contained within is interrupted resulting in the exhaustion of supplies below ground leading to ill-health and a shortened lifespan.

78 See Soil Biology in Agriculture, http://archive.dpi.nsw.gov.au/__data/assets/pdf_file/0006/166920/soil-biology-agriculture-intro.pdf.
79 See Overview of plant defences http://www.apsnet.org/edcenter/intropp/topics/pages/overviewofplantdiseases.aspx.

Landscape designers can address such constraints by maximising available soil volumes for plants, reducing the amount of soil surface sealing, and ensuring access below sealed soil for routine applications of organic matter or fertilisers.

STEPS FOR APPLYING BEST PRACTICE FOR SOILS AT CONSTRUCTION SITES

Step 1. Assessing Site Soils

Applying the following measures will ensure that soils at construction sites are managed in a way that benefits water filtration, detoxifying pollutants, and supporting healthy vegetation for shade and other amenity. Soil assessment must be undertaken by a CPSS (Certified Professional Soil Scientist) accredited soil scientist.

+ In many situations, it may not be possible or practical to specify designer soils for landscape outcomes, and we must work with site soils. Urban environments have produced a new class of soil termed Anthroposols by soil scientists. These, as the name suggests, are human-made soils and are far removed from any semblance of natural soil. They are often heavily modified, mixed, contaminated, contain rubble or other debris, and can have little in the way of soil for plant growth.
+ The task for the soil scientist is to ensure proper collection of samples from these soils and test them against the soil specification. In these cases, a soil specification will be used to define appropriate parameters against which the soil will be evaluated. The soil scientist will then determine if the soil meets the specification and if not, what amelioration is required to bring it to compliance, or if that is not possible, to make the soil fit-for-purpose. The focus is to work with the site soil as much as possible to limit the need for soil disposal or importation of new soils.
+ Site soil assessment will require testing for contamination as per the EPA's IWRG621 – *Soil Hazard Categorisation and Management*. This ensures that risks associated with contamination are identified and managed to prevent human or environmental impacts.

Step 2. Determining Soil Composition

+ If the site soil is suited to the intent of the landscape design with or without modification, the next challenge is appropriate management of that soil. This includes topsoil / subsoil separation at excavation, stockpile management, backfilling operations, and appropriate compaction levels at backfilling.
+ The complexity of soil ecological function and the agents of ecosystem service delivery are concentrated in the surface layers. Examination of a soil profile shows the concentration of plant feeder roots in the topsoil and this is the area where soil biological activity is highest. These topsoil layers can be thought of as the soil's digestive organ as this is where most decomposition and liberation of nutrient takes place. If these layers are mixed or buried or compacted to a high level, it is clear that the functioning of this soil will be grossly impaired.
+ In many situations design solutions will require the use of site soil in conjunction with introduced soils. This can allow the best of both worlds. The designed or specified soil will be optimised for vigorous growth and the connection with natural soil will allow extension of large root systems to access supplies of deep water during dry times. Similarly, where turf is an important part of the landscape design, the turf soil will be optimised to manage high traffic but the native soil beneath will be modified to allow deep rooting and access to water and other nutrients.
+ Green walls require careful selection of growing media depending on the degree of exposure to wind and light to ensure water supply and reserves are suited to the needs of the plants. Interior landscaping is often subject to considerable load limitations restricting saturated bulk density but requiring optimum growth and longevity of plants.

Step 3. Managing Soils During Landscape Excavation

+ Management of the soil at excavation, stockpiling and backfilling is critically important. Research has shown that soil biological function, carbon sequestration, and nutrient cycling can be severely compromised through inappropriate handling and storage of soils[80]. Because many site soils may not have ideal characteristics for plant growth it is additionally important to handle soils in a way that preserves positive attributes for re-use.
+ Excavated soils must be stripped in a way that preserves topsoil and subsoil in separate areas. Stockpiles should be no taller than 1m and must not be trafficked during or after stockpile construction. They should be fenced to prevent access and signposted to identify origins with a view to returning the soil to the location from which it was removed.
+ If stockpiles of excavated soil are to be stored for longer than one month they should be seeded with a sterile grass to maintain soil function.

Step 4. Managing Soils After Construction

+ Backfilling operations should be a reverse of excavation with subsoil placed at depth and compacted well. Topsoil should be placed above and should be lightly compacted to ensure its structure and air pathways are preserved.
+ City soils bear the hallmarks of centuries of activity. Some soils hold important archaeological records while others will show signs of more recent activity. The fact is that almost all city soils are disturbed and for this reason, sites should be assessed on a case-by-case basis so that the individual characteristics of each soil can be evaluated against the relevant specification and modified as required.

What do 'Soil Structure' and 'Structural Soils' mean?

Soil structure refers to the arrangement of soil aggregates and pore spaces. It is this arrangement, together with the organic content, that provides the basis for soil health. A healthy soil allows free movement of air and water, easy access for plant roots, and suppression of pests and disease. Healthy plant growth is achieved when all the influencing soil factors are in balance.

Structural soils are a specially designed supporting soil which provides for both a healthy growing medium plus a stable base onto which roads and pavements can be laid. This structural soil allows for the needs of both the landscape architect and engineer to be met. Structural soils can be achieved by either using a blend of large (63mm) aggregate rock plus a fine textured soil, or by installing strata vaults which are plastic structural units with large spaces for soil.

Further guidance can be found in:

Leake & Haege (2014) Soils for Landscape Development – Selection, Specification and Validation. CSIRO Publishing.

Calkins M (2012) The Sustainable Sites Handbook. John Wiley and Sons.

80 See Soil Stockpiling for Reclamation and Restoration http://conservancy.umn.edu/bitstream/handle/11299/59360/4.7.Strohmayer.pdf?sequence=1.

BEST PRACTICE NOTE
10.8 TREE REPURPOSING: HIGHEST AND BEST USE

BACKGROUND

The Metro Tunnel Project will introduce two nine-kilometre rail tunnels from Kensington to South Yarra, tunnelling underneath Swanston Street with five new underground stations to be built at Arden, Parkville, CBD North, CBD South and Domain. The project is setting new benchmarks for sustainable outcomes including the articulation of highest and best use principles for tree removals to support sustainable living and long-term management of urban environments.

TREE REPURPOSING: HIGHEST AND BEST USE

MMRA in consultation with tree asset owners has developed this 'highest and best practical use of trees' best practice note to facilitate the effective repurposing of trees to be removed from the project area.

Two categories of use have been determined as detailed overleaf.

MMRA or its delivery partner will work to achieve a Category A outcome wherever possible and repurposing options developed in partnership with local councils and /or the tree owner e.g. University of Melbourne.

Figure 1: Example of tree repurposing in City of Greater Dandenong.

Category A – Art, Creative, Ecological and Community Uses

Trees allocated for 'Category A' use will be used for the following projects:

+ Artwork – Projects with University of Melbourne and other stakeholders (e.g. log sculptures).
+ Interior Design Projects (Construction/Furniture).
+ TAFE training programs or similar.
+ Playground – Use the trees for both structural and non-structural playground equipment.
+ Ecological – Creation of habits (including aquatic) within local areas to facilitate biodiversity and habitat development (e.g. Logs for Landscapes).
+ Cultural and Heritage Commemoration – Possibility of using trees with historical or cultural (Indigenous and non-Indigenous) relevance for the ceremonial projects.
+ Community – Developing partnerships with local community groups for alternative uses for the trees (e.g. donating logs to 'Men's Sheds' for woodworking classes).

Category B – Mulching

Trees allocated for 'Category B' will be mulched on or off-site for use by Metro Tunnel Project stakeholders in the first instance; community groups or the tree removal contractor. The use of trees as mulch is considered a highly beneficial re-use option for trees that require removal.

STEP 1. PREPARE A TREE REMOVAL PLAN

Where it has been confirmed through the design process that tree removal is unavoidable, tree asset owners will advise MMRA or its delivery partner which repurposing strategy is to be employed.

Consideration will be given to the species, age and condition of the trees to be removed.

It is anticipated that many of the mature trees to be removed will be hollow and suffering from decay and therefore not suitable for many of the re-use options. In some instances, the quality of the timber will only be confirmed once the tree has been felled.

STEP 2. IMPLEMENT TREE REMOVAL PLAN

Once a tree has been approved for removal, the following steps should be implemented:

1. Confirm logistics for the implementation of nominated Tree Repurposing – Highest and Best Use strategy ensuring that the removal methodology is consistent with the proposed reuse.

2. Where required, organise for transport of the tree to a suitable location identified by the owner of the tree.

3. Implement necessary fauna management requirements. This may include passive or active relocation of fauna, installation of nest boxes, and installation of devices to prevent fauna from re-inhabiting trees identified for removal. See *Metro Tunnel Best Practice Note – Wildlife Transition in Construction Areas*.

4. Implement tree protection protocols for any adjoining vegetation that does not require removal.

GLOSSARY

Alternative water sources. Sources of water which are not sourced from natural catchments (including groundwater and river water) and are non-potable, including recycled wastewater, rainwater and stormwater.

Base case. The measurement of existing conditions e.g. existing tree canopy cover, within a defined area. The base case is used when tied to a sustainability target.

Biodiversity. The totality of living animals, plants, fungi and micro-organisms in a region; the variety of life in all forms, levels and combinations. Definition as per Green Building Council of Australia.

Biodiversity sensitive design. Urban design that deliberately integrates existing biodiversity assets into solutions that enhance outcomes for biodiversity and people.

Biophilic Design. Seeks to create good habitat for people as a biological organism in the built environment that advances people's health, fitness and wellbeing. Leads to the creation of spaces that are inspirational, restorative, healthy, as well as integrative with the functionality of the place and the (urban) ecosystem to which it is applied.

Biophysical boundaries. Also known as 'planetary boundaries' from the Stockholm Resilience Centre's hypothesis that there are nine hard physical boundaries that define a 'safe operating space for humanity'. These are: climate change, biodiversity loss, biogeochemical, ocean acidification, land use, freshwater, ozone depletion, atmospheric aerosols, chemical pollution. It also relates to the depletion of earth's natural capital monitored by the MIllennium Ecosystem Assessment.

Canopy cover. The amount of tree canopy cover over an entire area e.g. the land area of a suburb that is covered by tree canopy i.e. that is vegetation over 3m in height.

Community input. Local knowledge and expertise that is to be sought from local community members and the likely end-users to maximise the effectiveness and opportunities for site design and greening.

Contaminated Land. Soils where the concentrations of hazardous chemicals exceed those specified in policies and regulations or are at such a concentration as to materially impact the development being proposed. Definition as per National Environment Protection Council.

Ecological Value Calculator. Assessment tool developed by the Green Building Council of Australia to determine the change in ecological value component of their Green Star Rating System.

Ecosystem. An interconnected and symbiotic grouping of animals, plants, fungi and micro-organisms that sustains life through biological, geological and chemical activity. Definition as per Green Building Council of Australia.

Ecosystem services. The benefits people obtain from ecosystems. Delineated in four categories — supporting, provisioning, regulating and cultural as per Millennium Ecosystem Assessment 2005.

Environmental Management Framework (EMF). Provides the governance framework to manage the environmental risks identified in an Environmental Effects Statement.

Environmental Performance Requirements (EPR). Performance requirements set out within an Environmental Management Framework that need to be met by contractors during design, construction and operation.

Fit for purpose use. Use of water or soil of a quality that is well-matched with the quality required for the purpose. For example, the highest quality of water is utilised for drinking water, whereas other uses such as irrigation can use 'fit-for-purpose' water such as treated stormwater or recycled water which will not pose a significant health risk under that use.

Green facades. Created by growing climbing plants up and across the facade of a building, either from plants grown in garden beds at its base, or by container planting installed at different levels across the building. Definition as per The Growing Green Guide.

Green roofs. A vegetated landscape built up from a series of layers that are installed on a roof surface. Definition as per The Growing Green Guide.

Green walls. Comprised of plants grown in supported vertical systems that are generally attached to an internal or external wall, although in some cases can be freestanding. Definition as per *The Growing Green Guide*.

Habitat corridors. Generally linear strips of appropriate vegetation linking two or more larger areas of habitat. Corridors may be continuous (such as along waterways) or interrupted (such as a chain of smaller patches). The effectiveness of the habitat corridor for a particular species or outcome will be determined by the size of the corridor relative to the movement ability of the species, the availability of required habitat resources within the corridor, and the strength of any barriers or other negative impacts along the length of the corridor. Distinction between corridors and links follows A.F. Bennett (1999) *Linkages in the Landscape*.

Habitat links. Interrupted habitat corridors, such as stepping stones. See Habitat corridors.

Human health and wellbeing benefits. Includes enhancing physical, mental and social wellbeing as a result of interaction with nature. Definition as per The Sustainable SITES Initiative.

Human thermal comfort. A means of describing occupant comfort that takes into account air temperature, radiant temperature, humidity, draught, clothing value and activity rates. Definition as per Green Building Council of Australia.

integrated design team. Should include, at minimum, the following roles: Owner and/or client; Professionals knowledgeable in design, construction, and maintenance; Professionals knowledgeable in sustainable practices; Professionals with expertise in vegetation, water, soils, landscape ecology, materials, and human health and well-being, selected to meet the unique constraints and opportunities of the project and its site. Definition as per The Sustainable SITES Initiative.

Introduced species. Plants or animals which have been introduced to a location outside their native range through deliberate or accidental human action.

Invasive species occur, as a result of human activities, beyond their accepted normal distribution and which threaten valued environmental, agricultural or other social resources by the damage they cause. *Australian Government Department of Environment and Heritage*.

Impervious surface. Ground surfaces that cause rainwater to runoff by preventing passage of water through the surface into the ground.

Living infrastructure. Refers to all of the interconnected ecosystems within an urban catchment. This includes the rivers, creeks, hills, valleys, soils, rainfall and climate present in the system, and the species of plants, animals, microorganisms and other biodiversity

MUSIC modelling. MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry tool produced by eWater which predicts the performance of stormwater quality management systems.

Native species. Plants or animals that are indigenous to Victoria and/or Australia. Definition as per *Victorian Planning Provisions, DELWP*.

Natural vegetation. Plants that have not been grown by humans. Can include regenerating native habitat (post-restoration), remnant native vegetation as well as areas of exotic vegetation.

Non-vegetated surfaces. Horizontal surfaces at ground level that do not include plant cover. These surfaces can include paving, crushed gravel, rocks, bare soil or mulch.

On slab. Soil or landscape that is placed above or disconnected to the earth, such as in rooftop planters, container pots, elevated landscape areas, or landscape areas that have a membrane or man-made material such as concrete or plastic liner between the growing soil and the deep soil or natural earth or ground below.

Open space. "Land that provides recreation and leisure benefits." This land can either be in public ownership (see **Public Open Space**), or in private ownership but with public use permitted (such as school sports fields). Definition follows State of Victoria's Planning Practice Note 70 Open Space Strategy. For the purpose of the Living Infrastructure Plan, areas of open space must be publicly accessible without restrictions on the timing of access. https://www.planning.vic.gov.au/policy-and-strategy/open-space-planning.

Operation Stage. Stage in MMRP when the final project has been delivered and the operation of train services within the twin underground tunnels has commenced.

Operational manual. "a document that describes in detail the processes and systems that a company uses to produce its goods and provide its services". Definition from Cambridge Business English Dictionary © Cambridge University Press, online.

Passive irrigation. The shedding of rainwater runoff (stormwater) from adjacent impervious surfaces into a soil area to support vegetation growth by increasing soil moisture. The area from which water is shed (catchment area) must be significantly larger than the irrigated soil area.

Patch. A Patch is a homogenous area of land cover that can be delineated from other land covers based on a distinct set of physical characteristics. For example, a Patch of vegetation can be identified based on the relatively continuous cover of grasses, trees and shrubs within an area.

Patch areas. Physical extent of a distinct patch feature, measured on an area basis (e.g., square metres (sq.m.) or hectares (ha)). See also **Patch**.

Permeable soil. Depends on the physical and chemical properties of the soil, notably particle size distribution (the range of particle sizes present), pore space, pore size and the continuity of spaces. As per Leake & Haege.

Pervious surface. Ground surfaces that allow rainwater to pass through the surface, generally to reach a below-ground soil and groundwater system. Examples include vegetated areas, bare soil and permeable paving.

Physical properties (soil). The physical characteristics of soil are made up of several properties: permeability (the rate at which water travels) and water holding capacity, porosity, texture and compaction. All these factors alter the soil quality and have a direct consequence on plants.

Pollinator pathway. Habitat corridor composed of nectar-bearing plants and other features that support the presence of pollinators such native bees, butterflies, beetles and birds. See also **Habitat corridor**.

Potable water. Water intended primarily for safe human consumption. Also known as 'drinking water'. Definition as per National Health and Medical Research Council.

Post-construction. Final landscapes delivered by MMRP contractors when construction works have all been completed. See also **Operation Stage**.

Project boundary – To be determined by the station scope of works and defined by the Green Star project team for each Green Star project. This will typically be defined as the station area itself as well as all associated entries and exits. Definition as per Green Building Council of Australia.

Public lighting. Infrastructure that is designed to provide lighting for public spaces such as roads, car parks, shared paths, parks, public buildings and other spaces that may be accessed by the public.

Public Open Space. "land in public ownership and/or under public management that provides recreation and leisure benefits". Definition follows State of Victoria's Planning Practice Note 70 Open Space Strategy. See also **Open Space**. https://www.planning.vic.gov.au/policy-and-strategy/open-space-planning.

Research organisation. A Research Institution or other organisation that conducts basic or applied research as part of its primary purpose.

Structural soil. A volume of soil which benefits from reinforcement to support the required surface loading from buildings, cars or service vehicles without compacting the soil profile.

Soil sealing. Soil sealing refers to the creation of impermeable ground surfaces and underground structures that confine soil areas from rainwater and oxygen, harming the health of the soil. Soil unsealing refers to the removal of the confinement through the replacement or removal of the confining surface or structure.

Soil sequestration. The long-term storage of carbon in the soil. Definition derived from Ecological Society of America www.esa.org/esa/wp-content/uploads/2012/12/carbonsequestrationinsoils.pdf.

Soil volume. The length x width x depth occupied by soil, usually expressed in cubic measurement units (e.g. $metres^3$).

Subsoil. The layer below the topsoil that is imported or ameliorated from site subgrade conditions to form suitable rooting anchorage medium, moisture and nutrient store.

Sustainability targets. As set out in the approved Melbourne Metro Rail Tunnel Sustainability Policy.

Third pipe. A water distribution system with an additional pipe that allows the distribution of Class A recycled water.

Tree canopy cover. The breadth of tree canopy spread from all public trees, both native and exotic.

Tree plot. The physical underground and aboveground space allocated for a tree to be planted in.

Tree trench. A system of linear underground stormwater filtrations including soil and media to support healthy tree root growth.

Triple bottom line feasibility. The triple bottom line is a sustainability accounting framework with three components: financial, social and environmental. Triple bottom line feasibility ensures that the wider externalities and benefits of projects are considered to prevent decisions being limited to only financial factors.

Understorey plant. Shorter plants that grow under the canopy of trees.

Ultimate land manager. Also referred to as the end land manager, this is the organisation responsible for management and maintenance of the land post 2026 when the project is completed.

Urban forest. The sum of all urban vegetation including trees, shrubs, grasses including all species, both native and exotic.

Urban heat island. The phenomenon where urban areas show higher temperatures than surrounding rural landscapes both during the day and in the evening as per *VCCCAR's Planning for a Cooler Future: Green Infrastructure to reduce urban heat, 2013*.

Urban practitioners. Refers to wide range of different specialists that work in urban planning and design. The term is not intended to be restrictive, instead it is open to a growing list of different experts to increase the links and connection across different issues to deal with the complex nature of sustainable city planning.

Useful life expectancy (ULE). An estimate of how long a tree is likely to remain in the landscape based on health, amenity, environmental services contribution and risk to the community as per *CoM Urban Forest Strategy*.

Vegetation structure planting. A planting design that incorporates multiple layers of vegetation, consisting of any combination of ground cover plants, tall grasses and herbs (>10 cm), shrub and tree layers of varying heights.

Vegetated surfaces. Area of vertical and horizontal plant cover, including natural vegetation, garden beds, lawn, container plantings, vegetated roofs, walls and facades. For the purpose of Living Infrastructure Targets, this excludes tree canopy.

Water Sensitive Urban Design (WSUD). A set of practices, technologies and techniques designed to improve the management of urban water by utilising natural systems. Most commonly referred to as soil and vegetation systems used for stormwater treatment, including raingardens (or bioretention), swales, and passively irrigated tree-pits. Also known as Low Impact Design (LID).

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APPENDIX A: ENVIRONMENTAL PERFORMANCE REQUIREMENTS

The *Living Infrastructure Plan* provides supporting guidelines and measures to deliver and wherever possible exceed Environmental Performance Requirements.

ENVIRONMENTAL EFFECTS STATEMENT

The Environmental Effects Statement (EES) is an environmental risk assessment incorporating specialise environmental impact assessment studies. It identifies the scale of risks to the environment, and ways these risks can be managed.

ENVIRONMENTAL MANAGEMENT FRAMEWORK

The Environmental Management Framework (EMF) provides the governance framework to manage the environmental risks identified in EES.

The EMF lists out all of the Environmental Performance Requirements (EPRs).

ENVIRONMENTAL PERFORMANCE REQUIREMENTS

The Environmental Performance Requirements (EPR's) set out performance requirements that need to be met by contractors during design, construction and operation. They are enforced by MMRA via contract requirements.

Environmental Performance Requirements address legislative requirements.

Environmental Performance Requirement	EPR Objective	Supporting elements in *Living Infrastructure Plan*
Arboriculture AR1, AR2, AR3, AR4	'*Landscape, visual and recreational values* – To avoid or minimise adverse effects on landscape, visual amenity and recreational values as far as practicable'	Specifications requiring fit for purpose soil preparation to support healthy tree growth. Partnership with local government for tree planting and stewardship. Canopy priority areas to support heat island reductions, water quality and biodiversity benefits. 2 for 1 tree replacement requirement. Supporting temporary urban forests to mitigate amenity loss. Applied learning legacy opportunities: + Fit for Purpose Soils and their potential to maximise growth of urban trees dealing with climate change. + Trees pits and trenches to trial and monitor new planting solutions.
Historic Cultural Heritage CH17, 20	'*Cultural Heritage* – To avoid or minimise adverse effects on Aboriginal and historical cultural heritage values'.	Tree Protection Guidelines Species selection in line with Heritage Victoria approvals for registered landscapes e.g. Royal Parade, St Kilda Rd. Applied learning legacy opportunities: + The Return of the Eels collaborative project and monitoring opportunity with its links to traditional and current indigenous knowledge.

Environmental Performance Requirement	EPR Objective	Supporting elements in *Living Infrastructure Plan*
Surface Water SW2, LU3	'*Hydrology, water quality and waste management*: To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles.' 'LU3 – Arden Station. The design must include integrated water sensitive urban design (EPR SW2) and management of the extent of flooding across the site'.	Specifications requiring Urban Stormwater Best Practice Water Quality Performance Objectives. Requirement for all planting to be supported by passive irrigation and wherever possible, WSUD treatments will reduce the flow and pollutants reaching surface water. Applied learning legacy opportunities: + Soils for Stormwater project to trial and monitor different soil treatments and volumes to improve surface water outcomes. + The Return of the Eels collaborative project and monitoring opportunity with its links to traditional and current indigenous knowledge. + Soil contamination project to help address industry-wide gaps in knowledge, systems and communications for potential and actual land contamination. + Groundwater industry-wide gaps in knowledge, systems and communications for groundwater protection.

Environmental Performance Requirement	EPR Objective	Supporting elements in *Living Infrastructure Plan*
Aquatic Ecology AE1, AE2, AE5, AE7	‘*Hydrology, water quality and waste management*: To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles. *Biodiversity*: To avoid or minimise adverse effects on native terrestrial and aquatic flora and fauna, in the context of the project’s components and urban setting’.	Specifications requiring Urban Stormwater Best Practice Water Quality Performance Objectives. Requirement for all planting to be supported by passive irrigation and wherever possible, WSUD treatments will reduce the flow and pollutants reaching surface water. Applied learning legacy opportunities: + Moonee Ponds Creek Connecting Biodiversity and Community Project. + The Return of the Eels collaborative project and monitoring opportunity with its links to traditional and current indigenous knowledge. + Soils for Stormwater project to trial and monitor different soil treatments and volumes to improve surface water outcomes.
Terrestrial Flora and Fauna FF1, FF2, FF3	‘*Biodiversity* – To avoid or minimise adverse effects on native terrestrial and aquatic flora and fauna, in the context of the project’s components and urban setting’.	*Metro Tunnel Best Practice Note – Biodiversity Sensitive Urban Design* + Minimize loss of vegetation through design for legacy landscapes. + Avoid loss of native vegetation wherever possible. + Reduce spread of pests and pathogens through good vehicle and equipment hygiene. Recommendations for Integrative design process for public realm interface to MMRP Stations and Portal precincts to allow landscaping to support biodiversity goals. Applied learning legacy opportunities: + Environmental and Biodiversity Monitoring Project. + Multilayered vegetation in public spaces project opportunity. + Biodiversity for Soils Project. + Return of the Eels Project.

Environmental Performance Requirement	EPR Objective	Supporting elements in *Living Infrastructure Plan*
Groundwater GW3, GW5	'*Hydrology, water quality and waste management*: To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles.'	Specifications requiring Urban Stormwater Best Practice Water Quality Performance Objectives which will also support groundwater health. Applied learning legacy opportunities: + Groundwater industry-wide gaps in knowledge, systems and communications for groundwater protection. + The Return of the Eels collaborative project and monitoring opportunity with its links to traditional and current indigenous knowledge.
Landscape and Visual LV1, LV4	'*Landscape, visual and recreational values* – To avoid or minimise adverse effects on landscape, visual amenity and recreational values as far as practicable.'	Integrative design process for public realm interface to MMRP Stations and Portal precincts. Specifications to apply CoM Tree Protection Policy.

APPENDIX B: SUSTAINABILITY TARGETS

The *Living Infrastructure Plan* provides supporting guidelines and measures to deliver the Sustainability Targets in the Sustainability Policy.

SUSTAINABILITY POLICY

The Sustainability Policy provides the commitments of the MMRP project to sustainable design and construction.

SUSTAINABILITY TARGETS

To achieve the Sustainability Vision of excellent environmental, social and economic outcomes across all phases of the project, Metro Tunnel and its partners will meet a number of targets across key themes through the project lifecycle.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*

Excellence	+ Achieve an Excellent (minimum IS score of 70) 'Design' and 'As Built' certified rating under IS Rating tool.
	+ Achieve a minimum 5 Star Green Star certified rating under the GBCA 'Design' and 'As-Built' Melbourne Metro Rail Tool for all below ground stations.
	+ Publicly report sustainability performance on an annual basis.
	+ Demonstrate the implementation of innovative and pioneering initiatives in sustainable design, processes or advocacy that is considered a first in Australia and/or the world through the achievement of:
	  + innovative and pioneering initiatives during design and construction; and/or
	  + a broader market transformation towards sustainable development.
		The *Living Infrastructure Plan* supports the Excellence Targets by contributing to:
		
		GBCA Custom Tool for below ground stations.
		Management – Coordinated Approaches
		Management – Commitment to Implementation
		Management – Sustainable Cultures and Behaviours
		2.0 – Environmental Performance Targets
		2.1 – Services and Maintainability Review
		2.2 – Project Commissioning
		3.0 – Climate Adaptation Plan
		7.0 – Environmental Management Plan
		9.1 – Understanding Culture, Heritage and Identity
		9.2 – Enhancing Community Culture, Heritage and Identity
		10 – Urban Precincts
		11 – Safe Places
		15 – Lighting Comfort
		16 – Visual Comfort
		18 – Thermal Comfort
		19 – Greenhouse Gas Emissions
		21 – Sustainable Transport
		22 – Potable Water
		23B.5 – Low-Maintenance Design
		25 – Sustainable Products
		26.0 – Reduction of Construction and Demolition Water
		27 – Ecological Value
		28 – Sustainable Sites
		29 – Heat Island Effect
		30 – Stormwater
		31 – Light Pollution
		34 – Innovation

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*
		IS Rating tool for between stations Man-6 – Knowledge Sharing; Wat-1 – Water use monitoring and reduction Wat-2 – Replace Potable Water Dis-5 – Light Pollution Lan-1 – Previous Land Use Lan-2 – Conservation of On-Site Resources Lan-3 – Contamination and Remediation Lan-4 – Flooding Design Was-2 – Diversion from landfill Was-3 – Deconstruction/ Disassembly/ Adaptability Ecol-1 – Ecological Value (shared with GBCA) Hea-1 – Community Health and Wellbeing Hea-2 – Crime Prevention Her-1 – Heritage Assessment and Management Her-2 – Monitoring of Heritage Sta-1 – Stakeholder Engagement Strategy Sta-2 – Level of Engagement Sta-3 – Effective Communication Urb-1 – Urban Design Urb-2 – Implementation Inn-1 – Innovation
Urban Ecology and Vegetation	+ Double tree canopy cover by 2040 compared to the base case through the reinstatement of lost trees, planting of new trees, and the creation of improved growing conditions. + Ensure that the total amount of vegetated surface permanently gained post construction must be greater than total amount of vegetated surface area permanently lost. + At least 25% of new and reinstated planting areas must consist of diverse, multi-story plantings for biodiversity.	This *Living Infrastructure Plan* directly influences and enables these targets and accordingly provides measures and guidance to meet them.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*
Climate Resilience	Undertake a climate risk assessment and develop a climate change adaptation plan that addresses climate risks, and implement measures that ensure the infrastructure, stations and precincts are resilient to the impacts of a changing climate.	The *Living Infrastructure Plan* ensures our streetscapes are better adapted to changing climate by seeking to create more resilient landscapes through the provision of urban greening, water and healthier soils. These will contribute directly to: + reducing the urban heat island effect through shading and cooling + reducing the impact of droughts on urban vegetation through plant selection and climate-ready tree plots + supporting diverse habitats to enable adaptation options for flora and fauna + storage and sequestration of more carbon + attenuating stormwater flows during rainfall events.
Supply Chain	Develop and implement a project wide Local Content Strategy that establishes a framework for meeting or exceeding specific significant, strategic local content targets in accordance with the Victorian Industry Participation Policy Act 2003, including: + Collaborate with the Industry Capability Network to maximise opportunities for local Small and Medium Enterprise (SMEs) participation. + Develop bespoke local content targets for each delivery package within the project. + Identify local SMEs for potential participation in the Supply Chain for the project and demonstrate how these local SMEs have been alerted to potential tenders and supply opportunities.	The *Living Infrastructure Plan* supports the supply chain targets by: + supporting local supply chains e.g. procurement of tree stock and vegetation from Victorian SME's. + supporting skills growth in the urban sustainability industry through applied research and knowledge sharing that will increase the environmental and financial capacity of the private sector.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*
Communities	+ Implement initiatives that generate positive social outcomes to strengthen the economic, social and environmental well-being of the community. + Support the State's commitment to social procurement by implementing strategic procurement practices to generate social benefits beyond the products and services required. + Identify places of historical and cultural significance and minimise adverse impacts during construction and operation; develop and implement an interpretation plan that details initiatives to celebrate cultural connections and local identity. + Implement an independent design review process that enables technical experts to effectively address key urban design aspects of connectivity, accessibility, safety and identity. + Provide timely and relevant information to the community on milestones, project designs and construction impacts; proactively identify and communicate opportunities for the community to participate in project planning and delivery.	The *Living Infrastructure Plan* supports the Communities Targets via the proven correlation between' urban greening' and 'public health and wellbeing'. With public health and wellbeing as a central driver for the *Living Infrastructure Plan*, multiple priorities are emphasised to improve community engagement. This includes projects exposing people to greenery within stations, connecting communities above ground via a Cycle Line, and engaging with local community via tactical urbanism and interim green space interventions that help us better understand the needs of local communities.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*
Workforce	+ Identify and implement workforce initiatives that provide for the utilisation of new workplace skills and contribute to relevant sectoral, state and national targets. + Utilise Victorian registered apprentices, Victorian registered trainees or engineering cadets for at least 10% of the contract works' total estimated labour hours in accordance with the Major Project Skills Guarantee. + Achieve the Aboriginal Employment Target of 2.5% of total labour hours on the project. + Develop and implement nationally recognised accredited training and skill development programs and ensure that 20% of the workforce participate in Nationally Recognised Accredited Training. + Assess current and future workforce skill needs and develop a skills and labour gap plan and workforce profiles, including skill categories, required for the design and construction of major elements of the project. + Develop and optimise employment and training opportunities for economically and socially disadvantaged individuals during the construction and operation phase.	The *Living Infrastructure Plan* supports the Workforce Targets in the following ways: + Contributing to the development of world's best practice in delivery of urban planted vegetation, including climate-ready tree plots, more detailed information on the water and maintenance requirements for understory plantings, and enabling the sharing of this knowledge more widely with professionals in the associated fields. + Demonstrating that outcomes through PPP provide value added legacy outcomes that have not been possible under previous Business as Usual.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*

Energy	+ Achieve reductions in greenhouse gas emissions by a minimum of 20% below the base case (scope 1 and scope 2 emissions), excluding the use of renewable energy, for the infrastructure lifecycle.
	+ Of the remaining greenhouse gas emissions footprint, source a minimum of 20% of energy from renewable sources for the infrastructure lifecycle through either:
	  + generation of onsite renewable energy; and/or
	  + use of alternative fuels; and/or
	  + purchase of renewable energy from an Australian Government accredited renewable energy supplier.
		The *Living Infrastructure Plan* supports the Energy Targets in the following ways:
		+ by providing supporting initiatives for improved shading and microclimate which can in turn reduce heating and cooling needs of buildings
		+ potential sequestration of carbon through the use of biochar in soils.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*
Materials and Waste	+ Achieve a 15% reduction in materials lifecycle impacts (measured through EnviroPoints) below the base case. + Reduce Portland cement content in concrete by a minimum 36% measured by mass across all concrete used in the project compared to the GBCA reference mixes. + Source at least 95% of all timber products used for permanent works from re-used timber, post-consumer recycled timber, or from Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification (PEFC) certified timber. + Source at least 80% of steel used in construction from suppliers certified under Australian Certification Authority for Reinforcing Steels or similar international association or organisation. + Source at least 80% of fabricated structural steelwork from a steel fabricator/steel contractor which is accredited to the Environmental Sustainability Charter of the Australian Steel Institute (ASI) or similar international association or organisation. + Ensure that greater than 95% by volume of reusable topsoil and spoil (general fill), greater than 90% by volume of inert and non-hazardous waste and greater than 60% by volume of office waste is diverted from landfill.	The *Living Infrastructure Plan* supports the Materials and Waste Targets in the following ways: + High quality planting stock, and effective and appropriate growing conditions, maintenance and care during establishment to minimize planting failures and cost of replacement plantings. + All material from removed trees and vegetation will not go to landfill. Alternative uses will be found for every single tree removed for the project. + Highlighting possible uses for re-useable soil. Improving soil ecosystem health and biodiversity which can help increase nutrient cycling processes.

Theme	Sustainability Targets	Supporting elements in *Living Infrastructure Plan*
Water	+ Reduce total water use by a minimum of 5% below the base case. + Replace 20% of potable water with local non-potable water below the base case. + Reduce railway station use of potable water by a minimum of 30%. + Use rainwater and/or stormwater to provide passive irrigation to all tree plots and vegetated areas to support soil moisture needs. + Manage stormwater runoff from new or reinstated ground surfaces and roof areas to achieve the best practice water quality performance objectives as set out in the Urban Stormwater Best Practice Environmental Management Guidelines (Victoria).	The *Living Infrastructure Plan* supports the Water Targets in the following ways: + In achieving the target to reduce railway station potable water use, alternative sources of water can be integrated to support irrigation of nearby landscapes and biophillia elements in or on the station. + In achieving the target for provision of non-potable water supplies, water can be used to support irrigation of open space or landscapes (both in reinstated areas and on station sites and as an off-site contribution to wider non-potable supply schemes via a water use offset mechanism). Creation of permanent alternative water sources is important to the ongoing health and success of Living Infrastructure in the city. + Requirements for passive irrigation, and design guidance on use of rainwater and stormwater to support irrigation. This target is directly supported by the Living Infrastructure Plan. + Facilitation of the use of soils, vegetation and trees in reinstated landscapes to achieve best practice stormwater treatment by applying Water Sensitive Urban Design principles. + Support of increased capacity pipework in the Elizabeth Street catchment as part of the reinstatement of drainage, and complementary measures to intercept, store and slow stormwater.

For more information on The Living Infrastructure Plan:

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