City of Yarra

Embedding Green Infrastructure Guidelines - New Kerb Outstands

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ECOLOGY
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DESIGN

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CITY OF YaRRA

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1. CONTEXT

1.1 Context

As local government and the community experience pressures of climate change, increasing population growth and urban densification, there is a growing need for our streetscapes to perform a range of social and environmental services. These include increase of urban trees, cooling for mitigation of urban heat island effect, biodiversity connections, and contributions to identity, amenity and provision of liveability.

1.2 What is the purpose of this guideline?

The purpose of the guideline is to support successful integration of green infrastructure into streetscape works to improve the environmental and social quality and amenity of an area and to contribute to the longer term aim of improving the liveability of our cities and communities. While simultaneously delivering on Council's urban forest objectives to help cool the city and achieve broader economic and social outcomes for Yarra.

1.3 How to use this guideline?

This guide is intended for Council staff who are involved in infrastructure planning, design, construction and maintenance of three types of streetscape works:

I. New kerb outstands

II. Kerb and channel upgrades

III. Footpath renewals

The contents are divided as follows:

Chapters 1-2:

Introduction and benefits of Green Infrastructure

Chapter 3:

Project processes & design guidance for Green Infrastructure.

Chapter 4:

Worked example of retrofitting Green Infrastructure into a street in the City of Yarra.

Introduction to Green infrastructure

To understand the benefits of Green Infrastructure, see Chapter 2.

The 'How to' of Green infrastructure

- For a series of guiding principles for the selection and placement of Green assets and a step-by-step plan on how to implement them, see Chapter 3.
- For an overview of key site, safety and community considerations that can influence the success of Green assets, see Appendix B.

'Let's get technical' background and specifications of Green Infrastructure

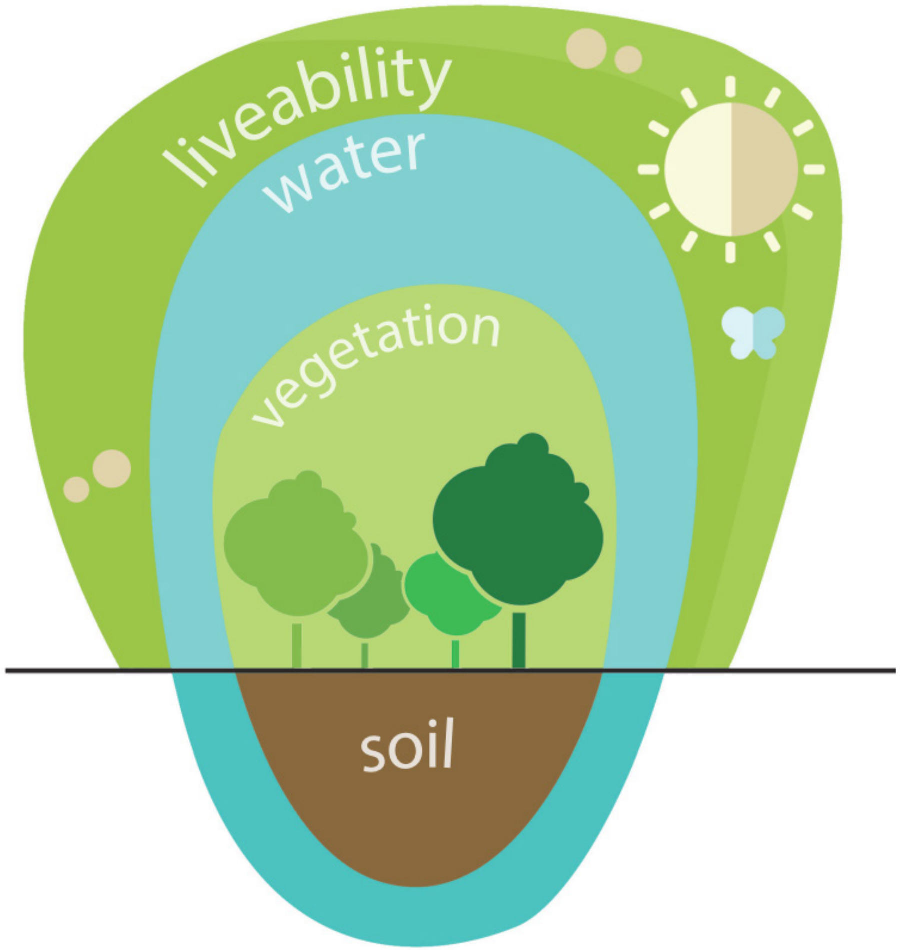
- For cross-sectional drawings and technical specifications that can be adapted for use within a project, see Appendices A respectively.
- For detailed guidance for the design of Green Infrastructure, see Appendix B.

1.4 What is Green Infrastructure?

For the purpose of this report Green Infrastructure (GI) refers to trees, shrubs, grasses and Water Sensitive Urban Design (WSUD) in urban environments. In other words, this report focuses on assets that jointly deliver on establishing a healthy urban forest and stormwater management needs.

Green Infrastructure addresses a direct and important link between greening and water management. Healthy trees and vegetation rely on the provision of soil moisture to thrive and flourish, while vegetated areas play a key role in absorbing, treating and controlling stormwater runoff in urban areas.

When planned and designed well, green infrastructure can passively deliver soil moisture to trees and vegetation and simultaneously treat and absorb urban stormwater runoff into the natural environment. These assets will help to address Council's urban consolidation and climatic challenges through the delivery of ecosystem services that enhance the well-being and prosperity of its local community.



2.

BENEFITS OF GREEN INFRASTRUCTURE

Uniting the complementary but often separate objectives of urban forestry and stormwater management can simultaneously delivers a range of social, landscape and water management benefits:

Green Benefits

Benefits derived from urban forestry

- Mitigate the urban heat island (UHI) effect via enhanced urban cooling (evapotranspiration)
- Improve air quality by absorbing pollution and collecting airborne particles
- Create visual linkages that can promote movement and direction
- Lower vehicle speeds through the presence of trees
- Reduce risk of heat-damage to public and private infrastructure (i.e. roads, rails)
- Provision of shelter and habitat corridors for local biodiversity
- Improve soil health with increased soil permeability, water retention, microbial activity and erosion control
- Carbon sequestration
- Increase pollination

Blue Benefits

Benefits derived from improved stormwater management (WSUD)

- Reduce stormwater pollutants (e.g. sediments, nutrients, heavy metals) and protect the health of waterways and bays
- Offset potable water demand with passive irrigation supply and diversified water supply (rainwater and stormwater harvesting)
- Improve the health of landscapes and the establishment of trees
- Increase soil moisture and recharge groundwater
- Reduce risk of water-damage to public and private infrastructure from urban flooding
- Reduce demand on existing drainage systems and a need for further upgrades

Pink Benefits

Societal benefits for the community

- Enhance street amenity and character
- Enhance mental wellbeing from a greater connection to nature
- Improve physical wellbeing with attractive and cool recreational spaces and walking environments
- Enhance street safety by reducing wind speeds, sun glare and providing privacy
- Increase local business viability with increased street activity and tourism
- Reduce risk of water-borne health issues in open water environments (i.e. beach water quality)
- Reduce demand on emergency services with a greater resilience to climatic events (i.e. heatwaves, floods)

3.

PLANNING, DESIGN AND CONSTRUCTION PROCESS

Currently, Green Infrastructure is implemented opportunistically, often considered too late in projects and with a range of communication challenges between relevant departments. It is important to embed Green Infrastructure into existing Council works processes. To support this, we have developed a process flow chart that includes:

- Prompts for consideration of Green Infrastructure in streetscape projects and bringing in relevant expertise
- Criteria for identifying Green Infrastructure opportunities
- Decision-making process for Green Infrastructure planning, design and construction

The processes apply for the following streetscape works:

1. New kerb outstands
2. Kerb and channel upgrades
3. Footpath renewals

The following planning, design and construction process is common for all of these. A short guideline specific to each type of works is also provided.

3.1 Tieing into existing Council processes and documents

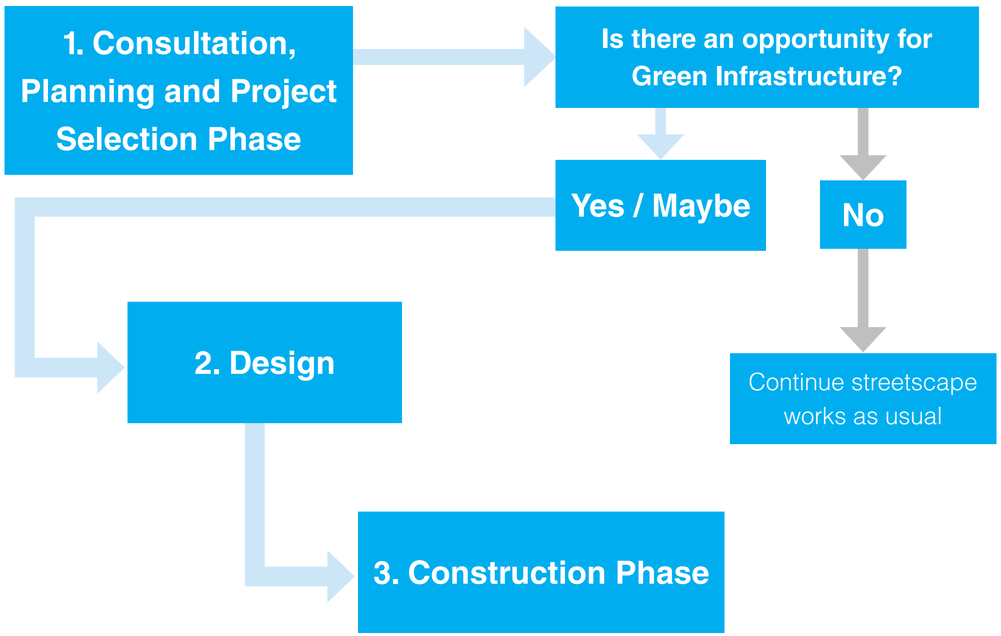
There are numerous Council processes and strategies which are relevant to Green Infrastructure, including a new drainage strategy (currently being developed), new biodiversity strategy (currently being developed), Local Area Place Making (LAPM) Policy and the urban design processes which focus on the design of activity centres across the City of Yarra.

The purpose of this guideline is to embed Green Infrastructure into Council streetscape projects where it may otherwise be overlooked. This is addressed in the first step of this process: Consultation, Planning and Project Selection.

Embedding Green Infrastructure in common works

- Process Flow Chart

The following steps are recommended to plan and implement Green Infrastructure within Council streetscape works projects. The steps are detailed over the following pages.

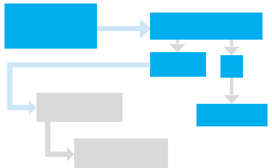


STEP 1: Consultation, Planning and Project Selection Phase

The first step in embedding Green Infrastructure into streetscape works is to consider GI early in the project's inception. It is also valuable to gain feedback from the community early on about potential types of Green Infrastructure for a given site.

This phase is addressed outside this guideline, through Council's LAPM policy or similar. At this stage, it is important to ensure Council's public works team consults with relevant disciplines, such as:

- Civil engineer
- Landscape architect
- Drainage engineer
- Environmental/sustainabilty officer
- WSUD designer
- Maintenance staff



Multi-disciplinary project team meeting

STEP 2: Design

3.2 Type of works

The following types of traffic works may be suitable for integration of Green Infrastructure:

Vertical deflection treatments

- Wombat Crossing

Horizontal deflection treatments

- Lane narrowing/kerb extension
- Slow points
- Mid-block median treatments
- On-road landscaping

Diversion treatments

- Full road closure
- Half road closure
- Modified 'T' intersection

Signs and line marking

- Marked pedestrian crossings
- Shared zones
- Threshold treatments
- Bicycle facilities

3.3 Street typologies

There are a variety of street typologies within the City of Yarra that may be applicable for implementing Green Infrastructure. The key street typologies are:

- Narrow residential street (typically no nature strip and constrained parking availability)
- Wide residential street (typically includes nature strip, ample parking, and may include bike lanes)
- Wide carriageway (opportunity and/or need for traffic calming treatments)
- Commercial street (typically congested, high competition for space)
- Major roads

3.4 Choosing a Green Infrastructure Design Response

There are a number of potential green infrastructure design responses that can provide increased canopy cover and meet urban forestry and stormwater management objectives. These are illustrated on the next page.

The following table indicates the likely suitability of a range of potential responses for various street types or 'typologies'. Which responses are likely to be suitable for the site?

Green Infrastructure design response matrix for new kerb outstand works

● Green = Suitable, ● Yellow = Maybe suitable, ● Red = Not likely suitable

	Open tree pits	Grated tree pits	Tree pits with vegetation	Permeable pavement	Proprietary Soil Systems
Narrow residential streets	Yellow	Yellow	Yellow	Yellow	Yellow
Wide residential streets	Green	Yellow	Yellow	Red	Red
Wide carriageway	Green	Yellow	Green	Red	Red
Commercial street	Red	Green	Red	Yellow	Yellow
Major roads	Yellow	Green	Yellow	Red	Red

Potential design responses

1. Open tree pit

2. Grated tree pit

3. Vegetated tree pit

4. Permeable pavement and structural soil to support trees

5. Proprietary structural soil systems (e.g. Citygreen Stratavault)

3.5 Design meetings and communication hold points

Ensuring the right team members are involved throughout the design is critical to project success. The following meetings or discussions are recommended during design.

Important design meetings (these may occur as separate meetings, or some may be combined)

Meeting purpose	Key representatives	Desired outcomes
Site layout	Project manager, civil designer, landscape architect, Water Sensitive Urban Design (WSUD) engineer	• Confirm site layout requirements, integrating with existing streetscape factors such as TAPM requirements, DDA (Disability Discrimination Act) compliance, footpath and bicycle path clearances. • Determine allowable Green Infrastructure design footprint • Consider connecting new green infrastructure assets or existing trees via underground soil trenches
Service investigations	Project manager, civil designer, WSUD/drainage engineer	• Review services information, including site survey and service proving • Confirm clearance requirements or other resulting constraints and any implications on design.
Planting and tree species	Landscape architect, arborist, project manager	• Select appropriate plant and tree species for the given site objectives and constraints (e.g. overhead obstructions limiting tree height)
Catchment and drainage elements	Project manager, drainage/WSUD engineer	• Identify potential downstream connection points and flow paths. • Estimate catchment area and treatment to catchment ratio • Consider integration with road to optimise treatment-catchment-area ratio for optimal tree moisture content.
Edge treatment and safety design	Project manager, WSUD engineer, landcape architect, civil designer	• Select appropriate edge treatments considering pedestrian safety, aesthetics and lowered surface levels (extended detention depths) for ponding.
Construction timing	Project manager, WSUD engineer, landcape architect, civil designer	• Review and align asset construction with other planned construction works surrounding the selected site to minimise construction costs and community disturbance.

3.6 Site Considerations

At the start of the design phase, there are many site factors to consider. The checklist below outlines key site considerations. These factors are looked at in more detail when selecting the preferred design configuration. Furhter guidance on these is provided in Section 3.8 - Design Factors.

Site considerations checklist

Consideration	Potential Issue	Checklist	
1. Overhead conditions	Tree canopy conflicting with overhead obstructions, including buildings, balconies, awnings, powerlines, tram lines, traffic lights, street lighting, bridges and signage.	Use Google street view and/or site visit or discuss with landscape architect to check: • Are there overhead obstructions? • Could a green infrastructure asset be integrated?	❑ ❑
2. Onground conditions	Tree pit conflicting with street facilities and activities, including footpaths, seating, dining, post/phone boxes, bins, cycling paths, bike/car parking, kerbs and channels, bollards, fences, driveways, signage, tram/bus stops, market stalls, electricity/water services.	Use Google street view and/or site visit to check: • Are there ground-level obstructions? • Could a green infrastructure asset be integrated?	❑ ❑
3. Underground conditions	• Stunted tree growth from restricted soil volumes and waterlogging. • Tree root conflicts with underground services.	• Check Dial Before You Dig (DBYD) • Check Council records (stormwater, water, sewer) • Map services on preliminary layout plan • Could a green infrastructure asset be integrated? • Early procurement of survey and services proving can help avoid design rework and delays later	❑ ❑ ❑ ❑ ❑
4. Sunlight and shade	Stunted tree growth	Use Google street view, Google Earth and/or site visit to check: • Will the site get adequate sunlight?	❑
5. Maintenance and local debris	Poor stormwater treatment performance from sediment and leaf litter clogging.	• Does the site or catchment have large or numerous deciduous trees? • Is the site adjacent to loose sediments or is there construction upstream?	❑ ❑
6. Safety and sight lines	• Safety issues in undertaking asset maintenance. • Poor interface with other site activities and users (i.e. pedestrian, traffic) can create a potential hazard. • Asset damage from conflicting site activities (i.e. heavy foot traffic, parking).	• Is the site immediately adjacent to high-speed traffic with limited space for access • Will trees or tall vegetation compromise traffic sight lines? • Does the site have high pedestrian or bike traffic? • How could maintenance staff safely access the site?	❑ ❑ ❑ ❑
7. Hydrology and hydraulics	• Poor stormwater treatment performance from uneven ground slopes. • Unable to achieve appropriate inlet and outlet connections. • Catchment size too large or small leading to vegetation health issues.	• Are the slopes appropriate? • Is an inlet achievable? • Is an outlet achievable? • Will the treatment-catchment-area ratio be appropriate?	❑ ❑ ❑ ❑
8. Site survey and services proving	**Late survey and services porving can result in design changes and delays.**	• Engage surveyor. (If engaging both survey and services proving coordinate investigations so services proving can use survey marks and CAD from survey.) • If underground services may impact design, engage service proving company to confirm exact location and depth	❑ ❑

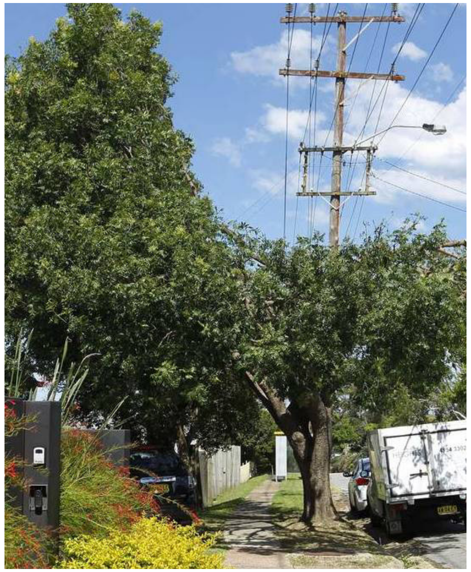
3.7 Selecting Preferred Design Configuration for New Kerb Outstands

The table below provides a set of questions for Council to work through as part of the process described in Chapter 3. These questions will help identify appropriate Green Infrastructure responses for the given site.

Design solution questionnaire

Question	(Yes)	(No)
Is the width of the outstand at least 2m?	Yes: Tree pits can be designed for outstands wider than 2m. A space for tree pit surface larger than $10m^2$ is ideal for open tree pits with vegetation.	No: Focus on smaller tree-pit system opportunities such as grated tree pits.
Does the site have a slope between 0.5% and 2%?	Yes: Surface runoff should be able to be directed to system with minimal erosion risk.	No: Surface runoff may not drain to system, or the site may be too steep, leading to erosion. Energy dissipation devices may be required to manage high inflow velocities.
Does the street have a slope between 0.5% and 8%?	Yes: Surface runoff should be able to be directed to system with minimal erosion risk.	No: Surface runoff may not drain to system, or the site may be too steep, leading to erosion. Energy dispersion devices may be required to manage high inflow velocities.
Is the crossfall of the street less than xx%?	Yes: Green infrastructure can be integrated into the outstand	No: Draining surface flows to the outstand will be difficult. Tree pits with a sub-surface inlet may still be achievable.
Does the site receive sufficient runoff? I.e. catchment >10x the size of the proposed canopy or vegetation footprint?	Yes: Outstand should receive sufficient runoff to support vegetation and stormwater treatment functions.	No: Catchment insufficient for Green Infrastructure. Invest in other sites.
Is there existing stormwater drainage to connect to?	Yes: Outlets can be achieved for tree pits.	No: Systems without drainage are prone to issues. Invest in other sites.
Will safety of sight lines be compromised by trees?	Yes: Manage trees in a way that preserves sight lines, otherwise focus on Green Infrastructure without trees.	No: Prioritise trees in response to maximise Green Infrastructure benefits.
Is the site within an area of high pedestrian traffic likely to walk over the outstand?	Yes: Grated tree pits provide a low-risk response for a busy site. Ensure appropriate edge treatment is applied.	No: Prioritise open tree-pits that enhance the streetscape. Ensure appropriate edge treatment is applied.
Are there underground services less than 1m deep?	Yes: Tree health depends on adequate soil volume and room for roots to grow. Focus on Green Infrastructure options without trees.	No: Prioritise trees in response to maximise Green Infrastructure benefits.
Are there overhead services?	Yes: Consult with landscape architect or arborist about appropriate tree species, or focus on Green Infrastructure without trees.	No: Prioritise trees in response to maximise Green Infrastructure benefits.

3.8 Design factors



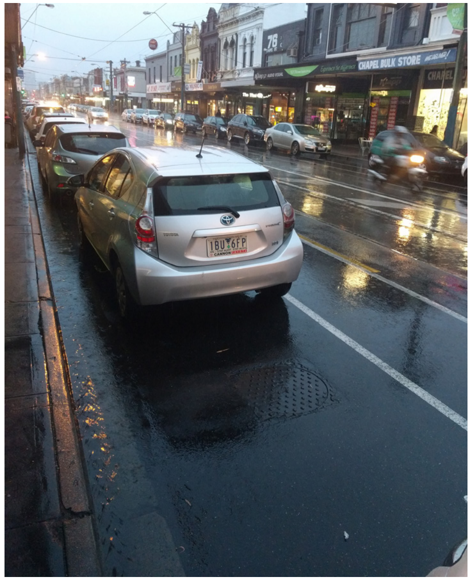
Overhead conditions

Trees can potentially conflict with other overhead infrastructure assets such as powerlines, tram lines, street awnings, and traffic lights etc. These pre-existing or planned constraints to taller green infrastructure assets must be taken into consideration with plant selection, placement and maintenance.

Underground conditions

Green infrastructure assets such as street tree pits require a deep underground soil media layer to grow roots and treat, retain and drain stormwater. Underground services can therefore be a major constraint.

A Dial Before You Dig (DBYD) check should be undertaken once a project location has been confirmed. This will help identify potential outfall drainage points and provide early notice of services that may need to be accommodated in the design or may limit the potential for certain types of Green infrastructure. Procurement for service proving should occur as soon as possible if the DBYD search indicates services may impact design works.



Catchment area

The catchment area is the area of land that will direct surface runoff to the asset. The catchment may comprise just the road and footpath to kerb and channel or include lots draining directly to the kerb. If the catchment area is too large the asset may experience flooding and pre-mature deaths of planting from waterlogging. If the catchment area is too small the asset may perform little stormwater treatment, dry out or experience pre-mature deaths of vegetation. To manage these risks, overflow weirs, drainage and deep submerged water zones can potentiall be incorprated into GI assets.

Catchment slope

Steep catchments can result in high velocities, erosion and scour in Green Infrastructure. Preferred site and catchment slopes for Green Infrastructure assets are between 0.5-5%. Catchment slopes of 5-8% may be considered with energy dissipation interventions such bands of dense, sturdy and consistent vegetation across the direction of flow to reduce velocities, and weirs to spread flows. Energy and flow spreading interventions can be costly and have a reduced probability of success.

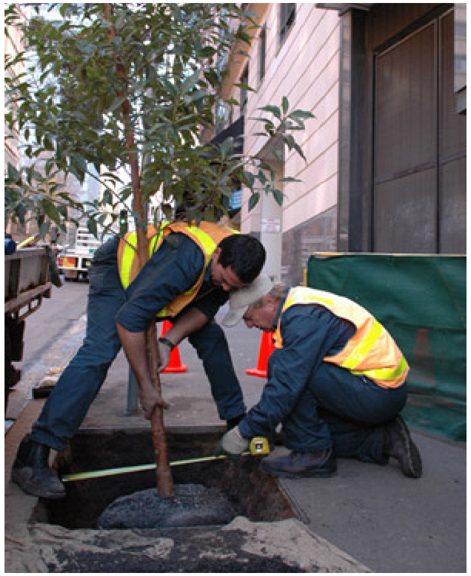
Soil volume

The provision of good soil volume around trees is essential to support tree health and canopy growth. In constrained environments, soil volume requirements may be met underneath load-bearing surfaces with permeable pavements and structural soil systems.

To support trees, soil volume should be one third of projected canopy, with a minimum depth of 1m. Structural soil systems can be used if soil volume cannot be achieved due to space constraints.

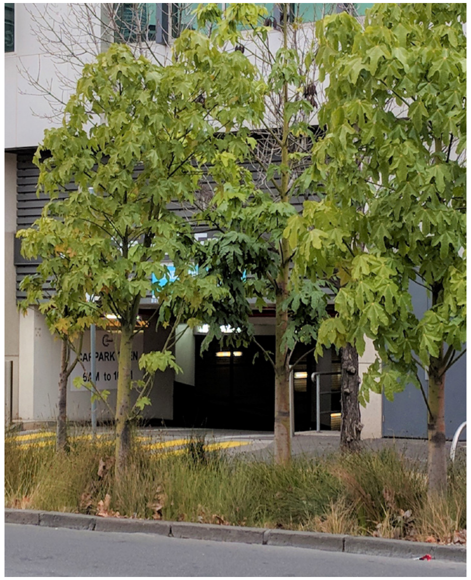
Soil media

Layers of soil media are used to filter out stormwater pollutants. This soil media is specifically designed and based on the required hydraulic capacity of the system. A landscape soil mix with good infiltration capacity and low nutrients is recommended for passively irrigated street trees. Bioretention media may also be used. Filter media is a highly permeable sandy-loam mix that allows the infiltration of significant volumes of stormwater.A minimum soil depth of 500mm is recommended for trees and other vegetation to support healthy root systems and soil moisture. For trees, a depth of at least 700mm is preferred.



Mulch

Mulch layers should be kept to a minimum (less than 30 mm) or preferably use no mulch. Dense understorey planting is prefered to manage weeds and moisture loss. Only non-floating mulch alternatives, such as rock mulch, should be used in green infrastructure assets.



Understorey planting

Tree pits can include a dense, diverse mix of understorey plants. These plants are essential for pollutant removal processes and are beneficial in reducing moisture loss and controlling weeds.

If underplanting are to be used, at least 50% of the planted species must carry characteristics for effective nutrient pollutant removal. Species must also be tolerant of frequent inundation and extended dry periods.

Arborists and/or water sensitive urban design expert should be consulted before the specification of plantings to ensure they suit the context and conditions.

Lowered surface levels

Tree pit surface levels are lowered from the surrounding area so they can capture and temporarily pond stormwater runoff. This depth is known as the 'extended detention depth'. This 'extended detention depth' is critical for proper functioning of the asset. This allows stormwater to slowly soak into the soil media and be treated by the system, providing stormwater quality improvements and soil moisture for greater tree health. A lower surface level will result in a larger volume of stormwater passing though the system, but must be managed through appropriate edge treatments. Generally, tree pit surface levels (including mulch layer) are lowered by 100-300mm from the inlet.

Soil slope

Green infrastructure assets are typically designed with a horizontal base that can capture and evenly distribute and infiltrate stormwater across its entire permeable surface area.

If the asset is sloped, the asset's functionality can be compromised and result in erosion, spillage, poor stormwater treatment, stunted plant growth and pre-mature deaths of vegetation. For steep sites that cannot be fully flattened, it is suggested that the suitability of green infrastructure for the site is reconsidered.

Slopes in these cases should run along the length of the asset with a flat base across its width.

Local debris and leaf litter

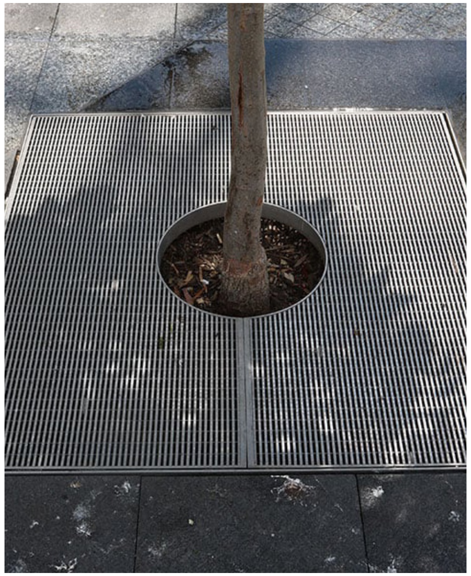
Street debris such as litter, sediment, and organics (i.e. leaves, sticks, weeds) are often washed into Green infrastructure assets during rainfall events. After multiple events, this accumulation of local debris can reduce the effectiveness of these assets and result in stunted growth and/or pre-mature deaths of plants. A further consequence can be a reduction in street amenity.

To reduce the likelihood of these outcomes, regular street cleaning and maintenance of Green infrastructure assets is required.

Street safety

Careful consideration must be given to how Green Infrastructure assets interact with their environment, particularly with pedestrians, cyclists and vehicles. In respect to residential areas, tree pits can be used as traffic calming measures although consideration must be given to preserving lines of sight. Tree guards, bicycle hoops, and bollards are commonly used protection devices to keep vehicles out of assets.

For pedestrians, the key safety issue to consider are tripping hazards. Tripping issues generally arise from lowered asset surface levels. Where possible, the asset interface should include batters and edge treatments to minimise the risk to pedestrians.



Tree grates

The surface of the grate should have small openings to allow air flow but prevent rubbish entering the tree pit.

Grates and guards should be designed to ensure they can easily be opened (e.g. guards and grates as two separable pieces).

Tree grates are highly customisable and can be designed to suit the aesthetic requirements of the site.

Grated tree pit edges

Selecting appropriate structural edges to support the grate of a tree pit is important. It is important to consider how the edge material will tie into the surrounds (e.g. heritage, civil works). The surrounds should also allow root growth close to the surface into surrounding structural soils. This can be achieved using a suspended slab for example.

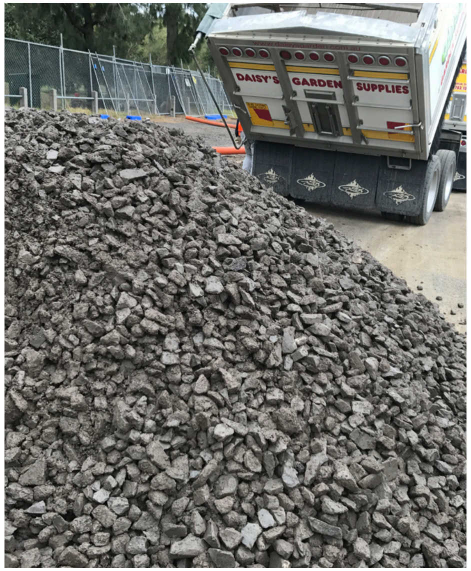
Poor edge material selection can lead to obstruction of root growth, release of organic/soil material and structural issues (e.g. caused by soil and tree root movement).

Permeable surfaces

Permeable surface materials allow water to soak and infiltrate down to the tree roots to help promote a healthy tree canopy. There are several material choices that can be utilised. Some of these include:

- Open graded asphalt
- Permeable concrete
- Resin bound gravel
- Interlocking pavers
- Permeable pavers

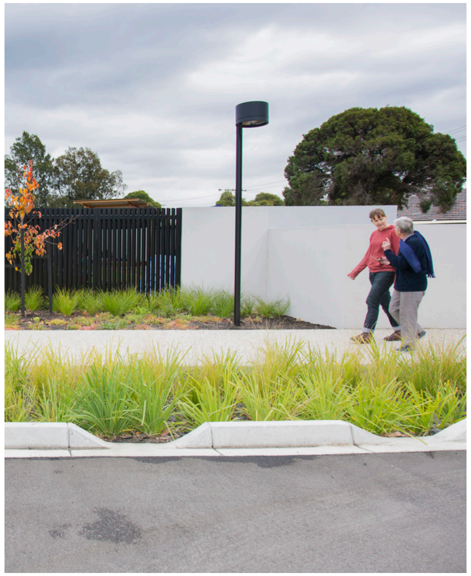
Permeable pavements should be regularly cleaned to maintain permeability. Pressure washing every 1-2 years would typically be adequate.



Structural soil systems

Structural soil systems provide greater soil volume for healthy tree rooting while also providing a stable base for roads and pavements. There are two main approaches:

- Structural soil - a compacted mixture of gravel and specially designed horticultural soil. The gravel compacts to provide the weight bearing capability. Comprises 20% soil by volume
- Structural root cells – modular units which assemble to form a skeletal matrix. Holdes a large volume of uncompacted soil for healthy root growth. Comprises 90% soil by volume.



Inlets

Inlets capture stormwater runoff and direct it to lowered soil surface levels for treatment. Inlets are highly customisable in their appearance and placement within the streetscape. Inlet design choices are important for vehicle and pedestrian safety, rate of maintenance, aesthetics, captured volumes of stormwater flows, and the health of planted vegetation. The main types of inlets for streetscapes are:

- Side kerb openings
- Channel inlets
- Grill plate side kerb inlets
- Modified side kerb inlets

Inflow velocities

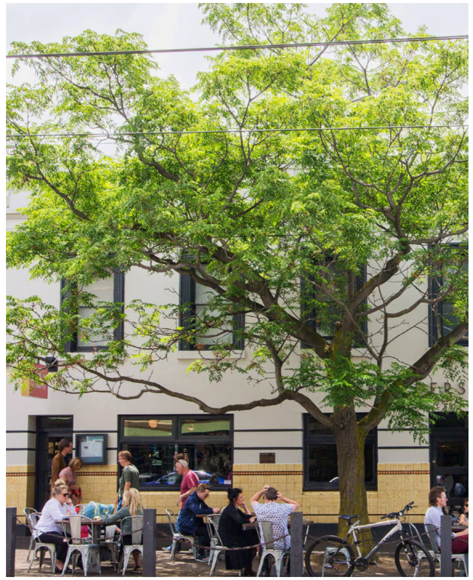
Inflows should be distributed where possible. Flush kerbs or multiple kerb breaks are most effective. Where flows are concentrated at an inlet, it is recommended that a flat concrete apron is used.

A band of dense and consistent vegetation at the end of the apron will encourage sedimentation and litter to drop n the apron. Inlet aprons with rocks or rocks in concrete are difficult to maintain and concrete is preferred where necessary.

The inlet should always be on a grade into the tree pit with at least 50mm of fall and slope of not less than 5% with 10% preferred.

Light and shade

Green infrastructure assets require a suitable amount of sunlight and shade to be successful. An appropriate balance between these depends on the specific flora used. Street trees for example require 6+ hours of direct sunlight per day to grow, whereas many grasses require only 2-4 hours per day to reach maturity. Specific flora requirements must be considered before selection and planting. Inappropriate plantings can result in sun damage, stunted growth, premature deaths and unusual growth paths as the flora seeks out more ideal growing conditions.



Tree canopy

Tree species selection is key to providing a full canopy, safe root growth, leaf litter management, habitat values and amenity values. Selected soil environments of tree pit sites and potential conflicts with other site infrastructure must be considered in species selection.

Species must also be tolerant of frequent inundation and extended dry periods.

Arborists should be consulted before the specification of trees to ensure they suit the context and conditions

Underdrainage (outlet)

Underdrainage aims to maintain aerobic root conditions by preventing over-saturation and water-logging of the upper root zone of trees. This also protects adjacent road infrastructure from excess soil moisture.

A slotted 'agi' drainage pipe within a narrow gravel or sand trench is often sufficient for tree pits. These convey treated stormwater from the base of the tree pit system to a stormwater drain. As a guide, underdrainage should be at least 500mm from the surface of the tree pit and 100mm or more above the base. Ideally it should be offset and not directly below the tree.

Ag pipes are critical to the performance of passive irrigation assets. There are options (e.g. pipe boring) that can be used to connect to drainage that is not near the proposed asset. The exception to this rule is where the proposed asset is set in sandy in-situ soils with a hydraulic conductivity equal or greater than the proposed tree media. In these cases, ag pipes are recommended but critical.

Edge treatment

Edge treatments define the border of the asset in the streetscape and deter the general public from straying into the asset. Edge treatment configurations include public seating, planted borders, bluestone kerbs, stepped sides, fencing and timber retaining walls.

While optimal combination of edge treatments are site specific, pedestrians should always be provided with clear and direct paths around assets, so there is a reduced likelihood of traversing through the system.

Steep batter slopes (e.g. 1H:3V) can be vulnerable to surface scour or erosion from inflows, as well as pedestrian traffic. A blue-stone step down can be used as an appropriate edge treatment to avoid this issue.

It is recommended that step-downs should be limited to 150 mm maximum.

3.9 Managing optimal soil moisture

The impervious surface area (m2) that directs stormwater runoff to a tree pit ('catchment') and the surface area (m2) of the soil volume dedicated for root growth in a tree pit ('treatment area') play an important role in providing optimal soil moisture for healthy tree growth and canopy development.

The treatment to catchment area ratio (TCAR) is a simple tool that can be used at the design stage to understand whether a tree pit asset will receive either too much or too little soil moisture, and if a change in design change needs to occur. The TCAR is formed as a fraction between the treatment area and catchment area. The following steps outline the steps for using the tool:

1. Measure the catchment area
2. Measure the treatment area
3. Calculate the TCAR

The catchment area for Green Infrastructure assets varying substantially depending upon the street and where it is placed within it. Properties, driveways, and footpaths upstream of the asset that drain to kerb should be included in the catchment calculation where relevant.

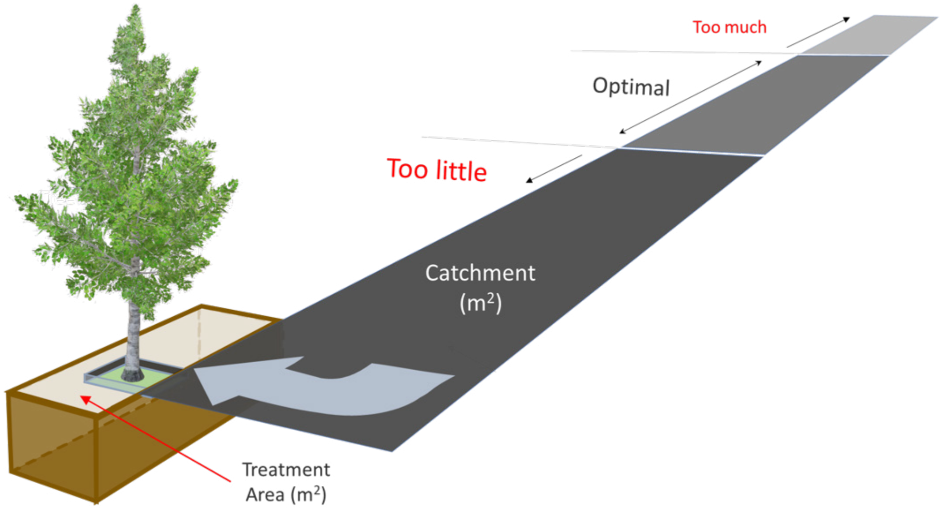
- A high TCAR increases the risk of a tree pit drying out too frequently and leading to stunted growth
- A low TCAR increases the risk of a tree pit being saturated for too long and leading to root rot

An appropriate TCAR can be designed for a tree pit by sizing its treatment and catchment area. The catchment area of a tree pit is often fixed and dictated by the streetscape slope and design. The treatment area may be constrained but can potentially be varied so the TCAR is within an optimum range.

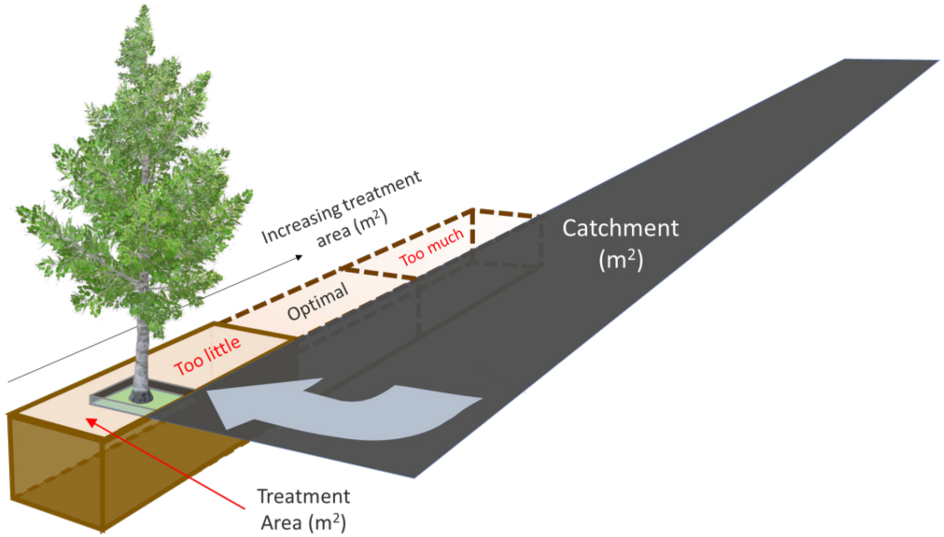
Treatment to Catchment Area Ratio (TCAR)

$$\text{TCAR (\%)} = \frac{\text{Treatment Area (m}^2\text{)}}{\text{Catchment (m}^2\text{)}}$$

Treatment Area Fixed
Size Catchment Area



Catchment Area Fixed
Size Treatment Area



TCAR Size

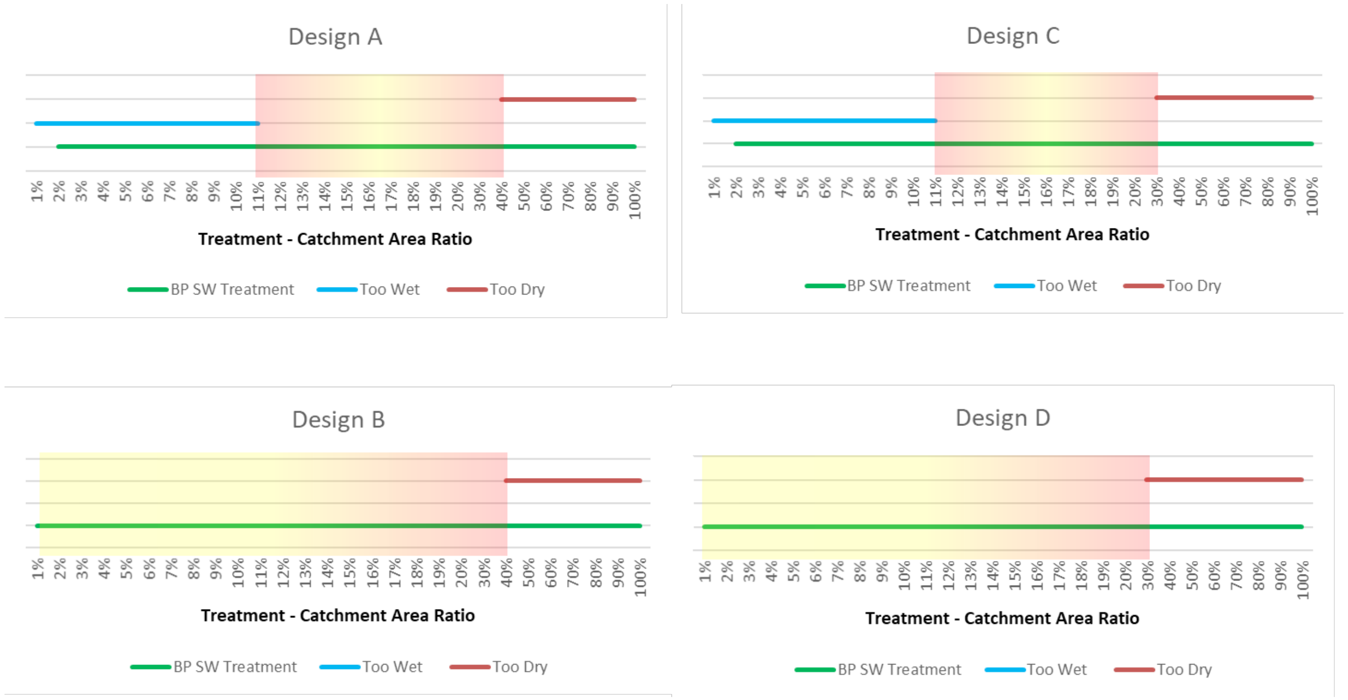
The optimal TCAR range for tree health is dependent on an array of factors including, but not limited to, local rainfall, soil type (i.e. saturated hydraulic capacity), and the use of a submerged zone.

Soil moisture modelling has been completed for the City of Yarra to understand the optimal TCAR range for tree health and best practice treatment for stormwater runoff. This exercise produced four design options (A, B, C, D) that offer their own unique TCAR range. These options are specified in the table on the right. The optimal TCAR range is provided in this table and also visualised in the following figures.

Other factors such as exfiltration and evapotranspiration were also tested to understand their sensitivity to changes in soil moisture.
The influence of these factors was shown to be insignificant.

Design Options	Submerged Zone	Soil Type	Soil Saturated Hydraulic Conductivity (mm/hr)	Minimum TCAR (%)	Maximum TCAR (%)
A	Yes	Landscape Soil	50	11	40
B	Yes	Filter Media	100	1	40
C	No	Landscape Soil	50	11	30
D	No	Filter Media	100	1	30

Optimal TCAR ranges (%) for the four design options



Legend

BP SW Treatment

TCARs that offer Best Practice Stormwater Treatment

Too Wet

TCARs that are not suitable due to prolonged periods of soil saturation

Too Dry

TCARs that are not suitable due to prolonged periods of dry soil

3.10 Design Feature Catalogue

The next step is to choose appropriate design elements suitable for the street context and proposed design response. These include the following listed elements. Descriptions and examples of each element is provided in the following pages. Once each element has been chosen, refer to the Technical Drawing Catalogue for technical drawings.

INLETS OPENINGS

TREE PIT SURFACE TREATMENTS

ENERGY DISSIPATION

OUTLETS

LANDSCAPE EDGE TREATMENTS

TREE PIT EDGING

PERMEABLE PAVING

Design Feature Catalogue (cont.)

INLETS OPENINGS AND GRATE STRUCTURES

DESCRIPTION	EXAMPLES	DESCRIPTION	EXAMPLES

Grill plate kerb opening inlets

- Transfer stormwater to the soil media horizintally via a grill inlet
- Captured volumes are senstive to the grill plate and adjacent channel design. Channels should be altered to slope to the inlet.
- Narrow openings to prevent litter entry, can be prone to blockage.
- Flush stainless steel allows easy streetsweeper cleaning

Modified Kerb Opening Inlet

- Bluestone kerb adapter for side entry into grated tree pit
- Entry is large to allow free surface water entry
- Entry height is small enough to prevent bottles entering system
- Inlet is graded down into tree pit to prevent build up of sediments within the inlet (behind the kerb)

Channel Inlets

- High flow capture efficiency
- Installed below the channel
- Transfers stormwater to the soil media via a grated, vertical drop inlet and an underground sloped passage.
- Collects sediments and fine debris
- Prevents the capture of large debris
- Preserves the existing kerb design

Channel Inlet

- Grated kerb inlet to tree pit
- Inlet is flush with road and kerb
- High capture efficiency
- Prevents litter entry, but not sediments
- Low cost grated surface inlet using combination of standard grate sizes.

Side kerb opening inlets

- Kerb openings are formed through the creation of 'gaps' in the kerb to allow stormwater to freely pass horizontally to the soil media.
- Is simple to construct
- Collects small and large debris
- Can allow high inflow velocities. Rock at opening can be used to dissipate energy upon entry Multiple kerb openings promote distributed inflows to occur.

Grate Structure

- Multiple trunk rings provided (small rings can be incrementally removed as tree grows)
- Tree guard is installed on separated cantilevered base. This allows the grate to be fully removed without removing the guard, making it ideal for easy maintenance access.

Design Feature Catalogue (cont.)

TREE PIT SURFACE TREATMENTS

DESCRIPTION	EXAMPLES	DESCRIPTION	EXAMPLES

Resin-bound gravel

- Expensive
- Good aesthetic finish
- Suited to high profile sites with heavy pedestrian traffic
- Prone to clogging. Will require cleaning to maintain permeability.

Permeable pavers

- Good aesthetic finish
- Suited to high profile sites with heavy pedestrian traffic
- Prone to clogging. Will require cleaning to maintain permability (pressure washing)

Vegetation

- Maximum vegetation and aesthic benefits
- Stormwater nutrient removal
- Vegetation also provides natural mulch and surface stabilisation

Bare soil

- Low cost soil surface finish
- Design may be susceptible to erosion and weeds
- Best suited to flat sites

Stabilised sand

- Advantages - cheap and easy to install and replace
- Disadvantage - can be damaged by street sweepers, and the sand can be deposited in drains.
- Not ideal adjacent to permeable pavement, as the sand can clog the pavement requiring increased maintenance regimes.

Porous asphalt, No fines concrete

- Not ideal for aesthetics (asphalt wrapped over tree roots)
- Concrete prone to cracking, which produces dangerous edges
- Prone to clogging. Will require cleaning to maintain permability (pressure washing).
- Not preferred

ENERGY DISSIPATION

DESCRIPTION

- Energy dissipation may be needed on sites with steep catchments
- Bands of dense, consistent vegetation across the inlet are most effective in slowing and spreading inflows.
- Concrete blocks can be used along kerb upstream to slow flows prior to entry
- Rocks and concrete blocks can be used at inlet to further dissipate energy.

EXAMPLES

DESCRIPTION

- Clifton Avenue, Clifton Hill
- Heavy energy dissipation with grate used for very steep catchment
- Rocks and gravel used here to dissipate energy entering tree pit, protecting tree pit from erosion

EXAMPLES

OUTLETS

DESCRIPTION

- Grated overflow pit captures overflows
- Raised above the ponding depth (extended detention depth)

EXAMPLES

DESCRIPTION

- Kerb openings at the upstream and downstream sides of the asset can be designed to allow excess stormwater to pass out of the system and continue downstream.
- The surface level must be lower than the surroundings to ensure regular stormwater inflows pond within the system, and do not quickly pass through and exit.

EXAMPLES

DESCRIPTION

- Trees can be located immediately upstream of standard kerb inlets to ensure runoff enters tree pit before entering stormwater network

EXAMPLES

Design Feature Catalogue (cont.)

LANDSCAPE EDGE TREATMENTS

DESCRIPTION

- Vegetation and kerb edges can be used to create a more flush visual effect, when the garden bed is sunken below the adjacent road.
- Retaining structures can deter pedestrians from walking over the tree pit, while providing seating.

EXAMPLES

DESCRIPTION

A combination of bollards and bicycle hoops are used here to deter traffic and pedestrians from this open tree pit. The tree pit is flush with the road to receive street stormwater runoff through slots in the kerb.

EXAMPLES

DESCRIPTION

- Edge treatment integrated as public seating on Chapel Street.

EXAMPLES

DESCRIPTION

- Broken concrete edge used to separate Green Infrastructure from vehicles along this centre median strip.
- Breaking the concrete edge allows runoff to enter the asset across the entire length of the system. This approach could also be used along one edge for solutions within nature strips, where they sit flush with the adjacent road.

EXAMPLES

TREE PIT EDGING

DESCRIPTION

- Bluestone edges used surrounding tree grate and along kerb
- Effective solution for heritage streets

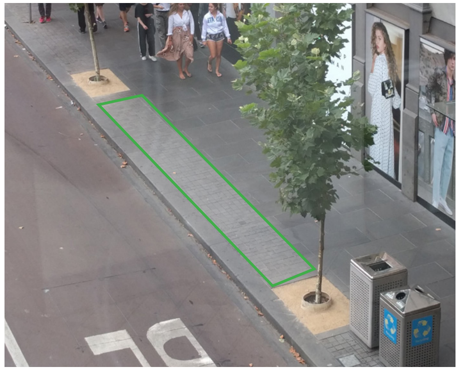
EXAMPLES

DESCRIPTION

- Staggered planted buffers can be used to deter pedestrian traffic and enhance amenity outcomes whilst also provide a lowered surface (extended detention depth) for ponding stormwater.

EXAMPLES

Design Feature Catalogue (cont.)

	DESCRIPTION	EXAMPLES	DESCRIPTION	EXAMPLES
PERMEABLE PAVING	• Permeable paving on footpath between open tree pits • Ties into busy commercial district with heritage bluestone kerbs • Narrow profile makes it ideal for busy footpaths		• Permeable asphalt carparking in residential street • Underground structural soils are connected to adjacent mature trees providing both soil volumes and water for improved canopy cover	

3.11 Estimating Cost

Establishing the estimated cost of the selected Green response is important to assess if the response fits within the project budget. The table below provides rates to help estimate the construction and maintenance costs of Green-Blue assets. Future maintenance costs should always be considered when budgeting for Green-Blue infrastructure.

An economic framework is available as part of the tooklit to help with understanding the life-cycle costs and also potential benefits of Green Infrastructure.

Asset	Asset Size (total area for project)	Indicative Construction Cost ($/m^2)	Indicative Maintenance Cost (per annum)
Tree Raingarden	10m^2 – 250m^2	$1000-2000	$15/m^2
Raingarden	10m^2 – 250m^2	$1000-2000	$15/m^2
Open Tree Pit	5m^2 – 50m^2	$1000-5000	$150/asset
Grated Tree Pit	5m^2 – 50m^2	$1000-5000	$150/asset
Permeable Pavement & Structural Soil	500m^2 – 5000m^2	$300-1000	$5/m^2
Strataflow Soil System	50m^2 – 250m^2	-	-

3.12 Street Typology Responses

Below are examples of three street typologies and various examples of Green Infrastructure responses. The following page provides sketches of before and after for three examples.

	DESCRIPTION	EXAMPLES OF GREEN INFRASTRUCTURE		
NARROW RES STREET	• Narrow residential street (typically no nature strip, and constrained parking availability)			
WIDE RES	• Wide residential street (typically includes nature strip, ample parking, and may include bike lanes)			
COMMERCIAL	• Commercial street (typically congested, high competition for space)			

DESCRIPTION	LOCAL CONTEXT

WIDE

Lowered tree pits with raingardens in large outstands

- Flush border wth road and channel to capture all surrounding runoff. Rock armouring on the channel entry is used to slow inlet velocities.
- Lowered garden bed surface allows ponding to occur and runoff to soak into the underlying soils.
- Trees are self-watering with the runoff, increasing tree health and canopy size.
- Stormwater pit inlet level is maintained and drains away excess runoff after garden bed is fully ponded.

BEFORE

AFTER

DESCRIPTION	LOCAL CONTEXT

WIDE RES

Lowered tree pits with raingardens in small outstands (intersection of Keele St and Gold St, Collingwood)

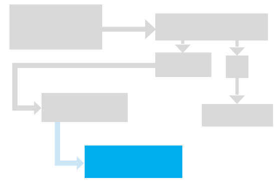
- Kerb breakouts level with the road to allow runoff to enter system
- Sunken base of system for extended detention, allowing water to pond and infiltrate into garden bed
- Extend size of system to incorporate existing field inlet, which would otherwise capture site runoff before it can enter the garden bed
- Retrofit kerb inlet to transform into a raised overflow pit

BEFORE

AFTER

	DESCRIPTION	**LOCAL CONTEXT**	
		BEFORE	AFTER
COMMERCIAL	Tree pit within oustand at intersection (Charles St and Swan St, Richmond) • Install structural soils under tree to give additional soil volume • Permeable paving adjacent to the tree to provide additional soil moisture		

STEP 3: Construction Phase



Stage	Checklist item	
Tender process	Tender drawings and specifications prepared	❑
	Tenders invited	❑
	Preferred tenderer selected	❑
Construction inception	Pre-construction meeting with designers and construction contractor. The purpose of this meeting is to discuss intent and purpose of GI, identify any potential difficulties or challenges and clarify any works the contractor may be unfamiliar with. Opportunities to improve outcomes may also be identified. Assess timing of construction and planting needs and schedule planting ordering. Plants numbers and species should be chosen by August and ordered in Spring or January at the very latest. See *Appendix D - Vegetation Specifications* for further information.	❑
Typical critical hold points (for inspection by designer or Council representative):	Testing of soil or transition and drainage media before placement	❑
	Testing of soil or filter media before delivery on-site	❑
	Testing of planting soil, structural soil, filter media, transition and drainage layer materials to site before placement	
	Inlet and outlet pit levels verified	❑
	Under-drainage	❑
	Soil, filter media and structural soil finished surfaced levels	❑
	Planting	❑
	End of establishment of 12 months after planting	❑

4.

WORKED EXAMPLE

NARROW SIDE STREETS

Worked Example - Narrow Side Streets, Richmond

Context

Richmond has many side streets which are very narrow. These streets may have residential apartments or commercial business along them. However the layout is fairly typical - narrow one-way or two-way streets, sometimes with parking on one side, with very narrow footpaths.

For narrow streets such as these, opportunities to incorprate GI are limited and there may not be room within footpaths to install trees without causing significant obstruction to pedestrians.

Where kerb outstands are being installed for traffic calming, or pedestrian safety at intersections, they are an ideal opportunity to incorporate GI, where it otherwise may be difficult. Near intersections is ideal, given parking is usually restricted near intersections (e.g. no standing zones within 10m of the intersection).

In this worked example, we look at a typical narrow side street without trees, and show how a kerb outstand could be designed to include trees with raingardens. In this case, the footpath on this side is very narrow, obstructed and of little use to pedestrians.

Typical street layout - narrow footpaths, single lane (one way), no trees

Narrow side street locality

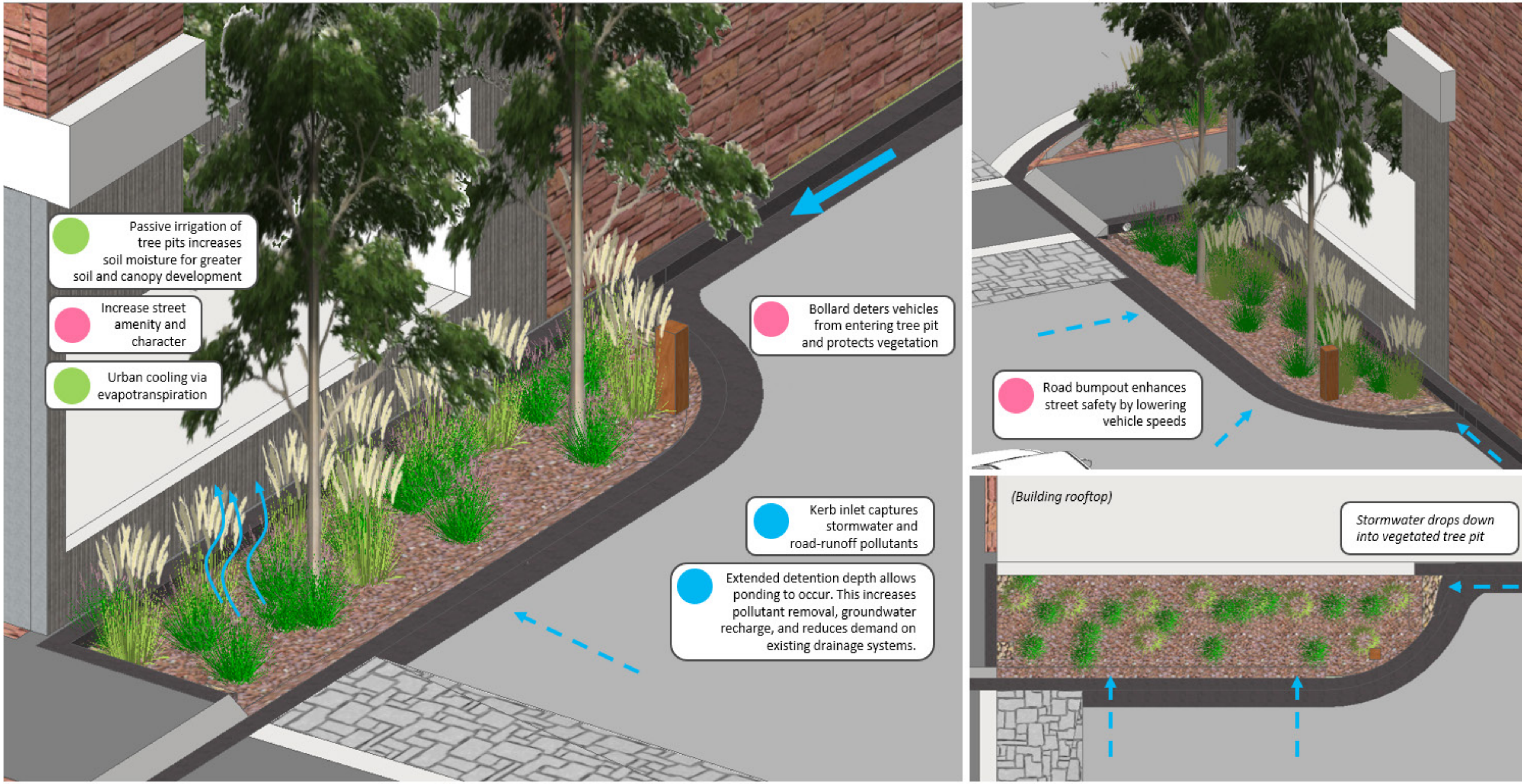
Design solution

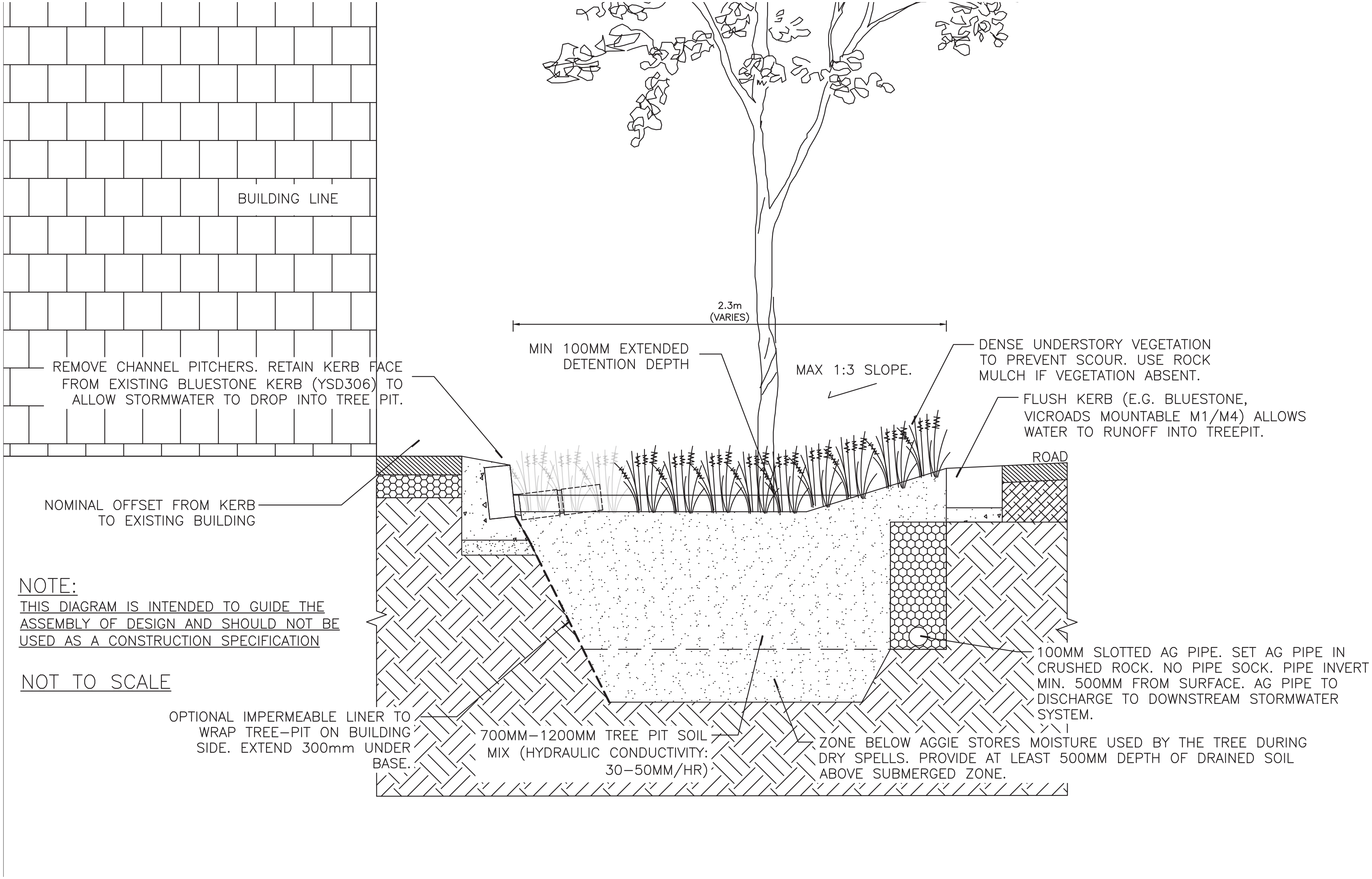
Kerb outstand extended up to 10m from intersection.

- Concrete kerb outstand at intersection, to allow safe pedestrian movement. Businesses can also place bins here if necessary.
- Passively watered trees in vegetated tree system. Inlet level with road surface to minimise the elevation difference to the surface of the system.
- Given footpath is already narrow, consider extended garden into the footpath to maximum surface area without extending too far into the roadway.

Existing narrow street


Designed to function as Green Infrastructure


Passive irrigation of tree pits increases soil moisture for greater soil and canopy development
Increase street amenity and character
Urban cooling via evapotranspiration
Bollard deters vehicles from entering tree pit and protects vegetation
Kerb inlet captures stormwater and road-runoff pollutants
Extended detention depth allows ponding to occur. This increases pollutant removal, groundwater recharge, and reduces demand on existing drainage systems.
Road bumpout enhances street safety by lowering vehicle speeds
(Building rooftop)
Stormwater drops down into vegetated tree pit



Note: Drawings are designed to guide concepts and are not to scale