### 2.2 Potential Stormwater Management Strategies

The following section summaries potential solutions that could be used to manage stormwater in Western Sydney.

#### 2.2.1 Targets

Based on the findings of the Urban Streamflow Impact Assessment (USIA) model, Streamology found that runoff from the developed catchments must be limited to 0.9 ML/ha/yr in order to prevent ecological degradation and waterway health decline. The most effective method of achieve the target Mean Annual Runoff Volume is by maximising the opportunity for runoff to dissipate in its immediate environment, limiting the volume ultimately reaching the waterways.

#### 2.2.2 WSUD Approaches and Management Objectives

Table 3 on page 31 presents several WSUD strategies which can achieve certain management objectives with varying effectiveness. It also highlights which strategies are effective depending on the design.

#### Rating the solutions

The low, medium and high categories are based on relative comparisons of each of the strategies. It provides a simple and effective means of rating strategies against one another. The table provides WSUD professionals a means of quickly assessing a strategy and its applicability to certain scenarios.

#### What is the "Sponge" Effect?

This management objective describes the ability of the strategy to provide enhanced absorption of rainfall and runoff in the landscape to reduce mean annual runoff volume. A high "Sponge" effect rating would indicate that the strategy can do more than attenuate peak flows. It provides mean annual flow reduction.

WSUD strategies can provide concentrated runoff retention or reduction providing means to achieve the 0.9 ML/ha/yr target.

#### Table 2. Applicable Locations for Stormwater Strategies

1	Preserve and Maintain Waterways and Riparian Areas
2	Urban Design/Housing Design
3	Erosion and Sediment Control
4	Permeable Paving
5	Rainwater Tanks
6	Downpipe Diverters
7	Green Roofs
8	Street Sweeping
9	Litter Control
10	Gully Baskets
11	Vegetated Swales
12	Gross Pollutant Traps
13	Wetlands
14	Floating Wetlands
15	Bioretention (raingardens)
16	Wianamatta street trees
17	Proprietary Filtration Devices



Х

Х

X			
Х			
	Х		
	Х		
	Х	Х	
		Х	
		Х	
		Х	
		Х	
Х	Х	Х	
	Х	Х	
Х	Х	Х	

	Peak flow reduction	Reduction in runoff volumes	Gross pollutants	TSS/TP/TN	Hydrocarbons	Cooling	Amenity	Cost effectiveness <sup>1</sup>	Sponge Effect	Maintenance Requirements
Preserve and Maintain Waterways and Riparian Areas						High		High	High	Low
Urban Design/Housing Design		Med				High	High	High	High	Low
Erosion and Sediment Control				High				High		Low
Permeable Paving	High	High		Med	Med	Med		High	High	Low
Rainwater Tanks	High	High				*			High	Low
Downpipe Diverters						*			Low	Low
Green Roofs						High	High	Low	Med	High
Street Sweeping								Low		High
Litter Control			High				High	*		High
Gully Baskets			High	Med			High	High		High
Vegetated Swales	Med			Med	Med	Low	Med	Med	Med	Low
Gross Pollutant Traps			High	*	Med			Low		High
Wetlands	Med	Low		*	Low	High	High	Low	Low	Med
Floating Wetlands				*		Med	Med	Med	Low	Med
Bioretention (raingardens)	Med	High	Med	Med	Med	Med	High	Med	High	Med
Watersmart street trees	Low	Med		Med	Med	High	High	High	High	Low – Med
Proprietary Filtration Devices			Med	*	Med			Low		High

Table 3. Alignment between various WSUD approaches and different management objectives.

<sup>1</sup>High = low cost, high benefit, Low = high cost, low benefit. \* denotes variable and design-dependent.

### Urban Design and Building Typology



Building over multiple storeys instead of single storey homes of similar living area can halve the footprint of a house. The smaller roof area and increased garden result in less stormwater runoff, as well as a range of household benefits associated with a larger yard, provided the allotment size remains the same.



The suspended construction strategy provides the opportunity to utilise screw piles in construction. In reactive soils the first metre of the soil profile will be exposed to moisture and thus movement. By grounding the piles below the most reactive layer of soil, the building structure can be immune to the majority of soil movement. Whereas traditional slab-onground structures are directly impacted by soil movement.

The infiltration trench option for the elevated strategy aims to capture the infiltration capacity of ground under elevated building. The infiltration trench provides the added benefit hydrating the reactive soils which reduces the chance for significant changes in moisture to occur, thus reducing occurrences of significant soil movement.

This construction method is also well-suited to areas impacted by saline soils.

**Rainwater Tanks** 

### **Downpipe Diverters**



Rainwater tanks can be a simple lot-scale solution for reducing stormwater runoff and supplementing mains water supply to households (as seen above). A common size in urban Australia is 5 kL.

A typical rainwater tank system involves capturing, screening, and storing roof runoff in tanks for subsequent (non-potable) reuse such as clothes washing, toilet flushing and garden irrigation. Overflows from the tanks can be directed to landscaped areas, other stormwater treatment measures (e.g. swales or bioretention systems) or the street stormwater drainage system.

Rainwater tanks can provide an alternative source of water for end uses such as hot water systems, toilets, laundry and gardens, thereby reducing the demand on centralised mains water supplies as well as minimising the overall volume of stormwater runoff. Other benefits are discussed further in Sharma et al. (2015) and Sharma et al. (2016).

Rainwater tanks can also be configured to provide varying levels of flood detention by having a dedicated 'airspace' or void in the top of the tank. When appropriately configured, and with the necessary regulatory controls, this can reduce the need for flood detention systems.



Downpipe diverters are a simple way of adapting existing downpipes so that rainfall is diverted to irrigate gardens and lawns (as seen above). This uses water that would otherwise create stormwater. The devices are low cost, have wide applicability, and can be easily retrofitted.

Downpipe diverters use a manually controlled flap valve to direct roof water from minor rainfall events to gardens or grassed areas, whilst large storm flows are automatically diverted into the conventional drainage system via the inbuilt passive bypass plumbing system. The device should be installed with an angled mesh leaf screen located above the diversion device. They are an alternative to rainwater tanks, particularly in areas where there are concerns with mosquitoes or limited area is available for tanks. They are best suited to use on downpipes where the runoff can infiltrate into soils, and on slopes that fall away from the building.

## Potential Stormwater Management Strategies

### Permeable Pavements



Permeable pavements can be designed with underdrainage systems that collect water for reuse or discharge, but more commonly, allow water to infiltrate into the subsoil (as seen above). They can be designed for a range of traffic loadings, varying from pedestrian foot traffic through to trucks. Like any pavement, poor engineering design that fails to provide adequate structural support for heavy vehicles can lead to uneven subsidence. Useful guidance on structural engineering design of permeable pavements is provided in Eisenberg et al. (2015).

Vegetated Swales



Vegetated Swales are simple vegetated drains that convey runoff, whilst providing an opportunity for sedimentation, seepage, and reduction in flow velocity. Swales can come in a wide variety of styles, ranging from formal turf-lined systems through to densely vegetated channels.

Swales work by infiltrating runoff into underlying soils, enhancing sedimentation from slowing the flow of water, and by filtration through the vegetation. Swales can be integrated with an underlying biofiltration trench for enhanced water quality performance.

Because swales provide stormwater conveyance, they can reduce or remove the need for underground pipe drainage. This can result in capital cost savings of up to \$5000 per allotment (Bligh Tanner 2014). The vegetation in swales is passively irrigated by runoff, minimising the need for irrigation in urban areas. As a green infrastructure measure, they contribute to mitigating urban heat island effects. If installed in open space or parkland, maintenance costs are minimised.

**Grassed Swales** 





Grassed Swales can be used in a wide range of urban settings, including centre median strips, road verges, within allotment landscaping, and in parklands. They should be considered wherever stormwater conveyance is needed, and where it is appropriate to have vegetation (as seen above).

Swales are best suited for slopes between 2 - 5%. On flatter grades, systems may require under drainage, and should generally be mass planted, not turfed, to avoid the need for mowing in potentially boggy areas. On steeper slopes (> 5%), check dams and/or rock-linings may be needed to minimise bed scour. Care needs to be taken when designing swales in locations with multiple driveway crossovers, as this can increase both installation costs and the risk of blockages. Wide verges that allow driveways to cross swales at-grade (rather than using a culvert) are preferable.

Key risks associated with swales are bogginess and ponding, especially if they are installed on a relatively flat grade, on heavy soils, or in areas subjected to regular vehicle traffic, and hence wheel rutting. In contrast, scour and erosion can occur if swales are located on steep grades, or on sandy soil. Localised flooding can occur if the flow capacity of swales is reduced due to debris, accumulated sediment, or the dumping of waste.

### **Constructed Wetlands**



Stormwater treatment wetlands are shallow vegetated water bodies that detain stormwater runoff and slowly release it after rainfall events. Stormwater wetlands differ from wastewater treatment wetlands in that they tend to have more variable water levels (a result of the variable nature of rainfall) and also treat influent water with much lower, and more variable nutrient concentrations.

Stormwater wetlands use forebay sedimentation, fine filtration, adhesion, biological uptake and transformation processes to remove pollutants from stormwater.

Wetlands are best located on low-lying flat land and are preferably sized at about 3 - 10% of the contributing catchment area. When wetland proportions are much smaller than this, they become fully charged with water after only small amounts of rainfall and may not have adequate time to drain between successive rainfall events. This can result in excessive inundation stress on the plants, and potentially plant failure (Hoban et al., 2006). Wetland sizing is often undertaken using MUSIC (Model for Urban Stormwater Improvement Conceptualisation, eWater, 2017). However, designers should be mindful that software tools do not provide guidance on plant viability, and it is possible to model excellent pollutant removal for a wetland configuration that, in practice, will not sustain healthy plants.

# Potential Stormwater Management Strategies

Examples in stormwater solutions integrated into the landscape...







### Green Roofs/Walls

Green roofs and walls cover a broad range of approaches to add greenery to the rooftops and walls of buildings in the urban environment. Systems include shallow ('extensive') and deep ('intensive') substrate roof plantings, trellis systems growing vines on facades, and vertically supported growing media (Figure 111).

Green roof systems can help mitigate urban heat island effects, reduce runoff, improve urban amenity, and provide insulation to buildings. They are suited to a range of urban environments, especially where the amenity benefits can be realised (i.e. the systems are visible and accessible). Installations must be easily accessible for maintenance, and roofs and/or walls need to have sufficient load bearing capacity (this may limit the ability to retrofit them on some buildings). Solar aspect and shading needs to be considered in site selection and system design.

#### How does this apply?

The high density apartment and business centre typologies can readily incorporate green walls and roofs to reduce the impact of impervious surfaces and provide opportunity for greater retention of surface runoff.



Figure 11. Various configurations of Green Roofs/Walls which provide cooling benefits, amenity and open space areas for people to relax.

## 2.3 Proposed solutions for the Western Parkland City

#### 2.3.1 Summary

The recommended solution combines the benefits of several Water Sensitive Urban Design measures to effectively mitigate runoff from developments within the localised landscapes.

Stormwater harvesting also plays a significant role in the water balance with both internal and external demands being considered.

Table 4 shows the recommended stormwater strategies proposed for the Western Parkland City. The following section provides a detailed explanation of each of the strategies.

#### Table 4. Recommended stormwater strategies for each land use category

	Permeable pavements	Bioretention 'Sponge Areas'	Wianamatta passively irrigated street trees	Rainwater reuse
Low density	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
Medium density	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
High density	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
Business parks	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
Industrial	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$



Figure 12. Business as usual versus aspirational permeability targets for South Creek



### Proposed solutions for the Western Parkland City



#### 2.3.2 Bioretention "Sponges"

Bioretention systems, also known as raingardens, are vegetated soil filters that treat stormwater by vertical percolation through a soil filter media. The use of saturated zones underneath bioretention systems is likely to assist in helping plants survive extended dry periods, as well as provide anaerobic conditions for denitrification. Figure 1414 provides a cross-sectional diagram of a typical bioretention system.

Water quality is managed through a combination of filtration, sorption, transformation, denitrification, plant uptake, and exfiltration. One of the major benefits of bioretention systems is in the slowing and reducing of runoff. A summary of recent research on the hydrologic benefits of bioretention reported significant attenuation of peak flows and runoff volumes, with an average volumetric loss of 50% across 370 monitored events, even for large storms (Q1, Q2) and for systems with impermeable liners or on heavy clay soils. The results of several studies are shown on the right in Figure 13.

Bioretention systems are very versatile in terms of shape and size and can be integrated into a wide range of urban settings (Figure 1515). Ideally, bioretention systems are located on sites where there is about 1 m of vertical fall between the inlet and outlet, to enable adequate filter media depth and under-drainage. However, bioretention systems can also be designed without under-drainage, allowing them to be created in a wide range of topographic circumstances.







Figure 14. Cross-sectional diagram of a typical bioretention system which can be readily adapted to many configurations

To manage the risk of failure, and promote better urban design integration, individual bioretention systems should ideally be limited in size to less than 500 m<sup>2</sup>, and service catchments no larger than three hectares.

Key risks for bioretention systems include:

- Smothering with sediment from erosion during upslope construction;
- Blocking of the filter media with retained sediment;
- Weed infestations:
- Excessive wetness that can result in slimes clogging the filter media;

- Plant death during long dry spells, or regular plant water stress due to using a filter media with a low water holding capacity. This can be mitigated by adding organic media to the filter media, and including a saturated zone underneath to provide irrigation via capillary rise;
- Vulnerable to poor construction practices given the number of elements that need to be constructed correctly; and
- · Herbicides and other toxicants in urban runoff.

Short-term studies in both controlled and field conditions indicate good pollutant reduction potential. However, there are few long-term field trials. The treatment performance of bioretention systems is variable, and while controlled laboratory studies

suggest reliable reductions in nutrient concentrations (Fletcher et al., 2007), most field studies show highly variable performance, often with negligible reductions in nutrient concentrations (for example, Hatt et al.,

2009; Lucke et al., 2015; Parker, 2010).

volumes of 50% (Figure 13).

Of course, the pollutant loads must go somewhere, and these sinks are either the matrix of the bio-filter (for P, heavy metals and sediment), plant uptake, or nitrification/denitrification for the N load. The field

studies suggest the primary treatment mechanism is the reduction in the volume of runoff, thereby reducing pollutant loads. A review of field studies by Hoban (2017) found average reductions in stormwater runoff

### Underdrainage (as required)

- Typical maintenance requirement for bioretention systems include:
- Weed management and supplementary planting;
- Litter removal;
- Coarse sediment removal; and
- Periodic flushing of under-drainage.
- Maintenance efforts can be minimised by:
- Ensuring there are trees and shrubs in the system to provide shade and help minimise weeds;
- Focussing on the effective establishment of a locally appropriate plant community;
- Ensuring the filter media has adequate organic carbon for denitrification reactions:

## Proposed solutions for the Western Parkland City



Figure 15. Bioretention basins incorporated into landscape areas.

- Organic material in the media to increase water holding capacity;
- Providing a coarse sediment forebay where high sediment loads are expected; and
- Ensuring the system is accessible for maintenance.

There is still insufficient scientific and anecdotal evidence to be confident about the long-term viability of bioretention systems in a range of climatic contexts, especially in arid and dry-tropical environments. Success has been variable, with a 15-year-old system in South-east Queensland, Australia having good vegetation growth and low maintenance requirements. However, there are many more examples of very poor design and implementation. Some systems that appeared to perform well for several years have then suffered vegetation die-back. There have been some prominent failures with very large bioretention systems (> 1,000 m<sup>2</sup>). Smaller systems, tailored into the urban landscape design, appear to have the best prospects of long-term success as they are more likely to receive ongoing maintenance and plant replacement. There are encouraging signs that systems with saturated zones beneath them have better plant performance, and presumably better pollutant reduction.

#### How does this apply to South Creek?

The landscape and urban form can be shaped to direct the majority of runoff into planted landscaping to attenuate runoff from impervious surfaces.

#### Challenges with conventional raingardens

Raingarden designs are limited by infiltration capacity of the local soils and its characteristics.

Highly permeable soil result in poor soil moisture retention to which plants and trees need to access to grow and flourish. Low permeability causes more runoff to bypass the raingarden completely. Also, water-logging of the soil can cause roots to rot causing plant and tree death.

The balance of soil storage, permeability and exfiltration will provide optimised conditions for plant and tree growth. The maximum function of rain gardens can only be guaranteed if vegetation is healthy and established. Thus we have devised a solution that engineers the local soils, regardless of the infiltration capacity, to provide a greater opportunity for trees and plants to access water.



#### 2.3.3 Water Smart street trees

Street trees have multiple purposes in the urban form. It can provide shading, urban cooling and provide aesthetic value in dense urbanisation. The value it can provide to stormwater management is often understated.

#### Importance of street trees

Street trees are widely accepted as valuable Council and community assets. They are recognised as elements of the landscape which can provide cooler, greener and more welcoming pathways for walking and cycling.

There is a distinct difference entering a green and leafy street with large and healthy trees growing along it compared to a sun-baked street with little to no shading. Trees provide improvements to air quality through their uptake of CO2.

Street trees are a catalyst in establishing urban habitat for fauna and establishing an ecosystem. Trees can also provide wind breaks to reduce wind speeds experienced at ground level.

There are also known benefits to human physical and mental health.

# What are their benefits to waterway health and urban heat?

Impervious paved areas prevent rainwater from infiltrating into the ground and instead shed water and pollution, these often have detrimental effects to downstream waterway health.

Street trees result in the modification of the urbanised hydrology through increased rainfall interception, infiltration and reduced surface runoff. A street of wellestablished street trees will experience fewer instances of flooding, contribute reduced stormwater flows and reduce pollution to water ways. This provides positive impacts when managing waterway health in

an urbanising catchment. Also, Western Sydney has known dry land salinity issues which can be mitigated by street trees that reduce groundwater recharge. For discussion on Salinity refer to page 20. Plastic lining is included in the proposed water smart street tree solution, ensuring water is retained in the shallow soil to promote evapotranspiration.

Trees are the most effective at creating cooler streetscapes. It has been shown that reduced air temperatures can be achieved by both shading and evapotranspiration. Cooler outside temperatures can also contribute to reduced building energy consumption. By improving thermal comfort and shading to pedestrian paths and footways, more residents are encouraged to use active modes of transport.

#### Urban Tree Canopy

The urban tree canopy can amplify cooling effects compared to a singular tree. A line of street trees can provide a green corridor. With a network of tree-lined streets a cool micro-climate grid is created.

Hence canopy targets as used in the proposed typologies, can encourage the creation of urban forests with broader benefits for the community.

The stormwater benefits of each individual tree are modest, however there is potential for widespread application, with a large number of trees having a cumulative impact, given that a typical street tree density in the inner city is about 100 trees/ha of street, corresponding to a 25% canopy cover.

#### Challenges with street trees

Local Governments acknowledge the importance of creating and maintaining extensive tree canopy in urbanised areas. However, as water scarcity increases, manual watering of street trees is simply not practicable. Traditional street trees are often heatstressed, have limited access to nutrients and water and often roots are damaged by construction, service trenches thus limiting uptake of water.

The sustainable solution for Local Governments to achieve healthy street trees is passive irrigation through connection to the stormwater system. Also, measures such as appropriately matching the tree species to the water availability is another way to ensure trees can establish successfully in the landscape.







Figure 16. Placement of street trees

#### How much water do street trees need?

Trees will use more water if it is readily available, or if it is scarce, trees will significantly reduce their water requirements.

A tree can only use as much water as it has access to in the soil (soil moisture). Soil moisture varies throughout the year and is lowest during late summer and early autumn. The maximum water use by a stand of trees growing in recharge areas will be the annual rainfall. Surface run-off and recharge that occurs between root systems, however, reduces the potential water use.

The water evaporated by trees is dependent on the availability of water, sunlight and leaf areas.

Other factors influencing tree water use include (Connellan, 2008):

- Water use characteristic of the tree species (High, Medium, Low)
- Size of tree crown area is the key dimension
- Density and area of leaves as reflected by the Leaf Area Index (LAI)
- Site climate evaporative demand
- Condition or health of the tree
- Stage of development of the tree
- Availability of water to the tree water stressed trees use less water than if water readily available.

Connellan (2008) developed an equation to predict tree water use incorporating these factors.

Resources have shown some species transpiring up to 320 L/day. It was found that middle-aged trees (20 years) have highly variable daily water use. The average was found to be 50 L/day (Agriculture Victoria, 1999).

#### Street trees grow faster with Stormwater

Research by Denman et al. (2011) shows that trees irrigated with stormwater grow about twice as fast as those irrigated with tap water (Figure 18). This was found to be the case across a range of tree species and soil types with saturated hydraulic conductivities from 4 to 170 mm/hr. This phenomena was observed in a residential development in Bundaberg, QLD. In the harsh dry climate

Simple designs allow runoff from kerb and channel to provide water into the root zone of street trees (Figure 2017). Passively irrigated street trees are increasingly being adopted by local governments such as Melbourne City Council (which has been trialling various designs for over 10 years), City of Sydney, Brisbane City Council, New York City, and in the UK.

Given that street trees often receive no irrigation at all, this approach provides not only a source of water, but also allows nutrients in stormwater to be sequestered by the trees, rather than being discharged to waterways.

Grey et al (2018) undertook an 18-month streetscape experiment comparing four stormwater tree pit designs, along with a control street tree planting, to identify design characteristics influencing the water balance and growth of newly planted trees (Acer campestre (L.)) in an established urban area dominated by clay soils. Trees in pits with an underdrain showed double the growth of conventionally planted street trees receiving no stormwater.

The stormwater quality benefits of each individual tree are modest, however there is potential for widespread application, with a large number of trees having a significant cumulative impact.



Figure 17. Healthy street tree that is passively irrigated compared to standard street trees which do not receive passive irrigation with stormwater located in Bundaberg, QLD. Healthy trees are required to provide urban cooling and shading for pedestrians.



Figure 18. Research shows trees grow faster when irrigated with stormwater compared with tap water. Source: Denman E.C, May P.B. and Moore G. A. (2011). The Use of trees in urban stormwater management. 12th National Street Tree Symposium

Tapwater

Stormwater

#### How much soil do street trees need?

By providing more opportunities to incorporate "green" in the landscape through allowances in the typologies we must also ensure that these areas can flourish and provide the benefits promised.

When planting medium to large trees in verges, on slab/rooftop gardens, in raised planters or pots, tree pits or where the "break out zone is limited" careful consideration must be made to ensure the trees can have adequate access to soil. Adequate soil volumes will provide access to nutrients and water, ample room to grow and reduce the likelihood of tree death in heat-stressed climates.

#### Soil Volume Calculator (Leake and Haege)

The Soil volume calculator for street tree health (Leake and Haege) can be used to specify soil rooting volume and is useful with tree planting in urban situations where soil may be limited.

It considers the following parameters:

- 1. Climatic growing conditions
- 2. Available soil moisture & water holding capacity
- 3. Physical soil properties & texture
- 4. Species selection
- 5. Available soil nutrients (for plant growth)
- 6. Maintenance, establishment and care
- 7. Proposed soil ameliorations
- 8. Shared root system & expected lifespan / replanting frequency.

The Western Sydney climate will significantly impact the soil volume required. Low annual rainfall and high evaporation rates will place significant pressures on street trees.

The assumptions conservatively consider the current practices regarding street tree installation, establishment and care. General site practices on development sites were also considered in the assessment.

However the proposed development typologies and street designs seek to steer away the detrimental conditions of the average urban development. Providing adequate soil volume for tree growth can result in double growth rate (Grey et.al 2018), 8-10 times the canopy cover (Hitchmough, J. 1994) and increase the life span of the tree (Skiera & Moll, 1992).



Figure 19. Recommended Minimum Soil Volumes Chart (Leake and Haege)





Figure 20. Examples of an urban street tree that receives stormwater runoff: Top image 2008, bottom image 2018

The Western Street Design Guidelines developed by the Western Sydney Planning Partnership Office adopt the following assumptions for tree soil volume (Table 55). The same assumptions have been adopted for the purposes of this work.

### Table 5. Recommended Minimum Soil Volumes for street trees (ASPECT Studio)

Tree Size	Typical Height	Recommended Minimum Soil Volume			
		Per tree in individual tree pit	Per tree in shared trench (typ. up to 3 trees)		
Small	To 4m high	8.65 m³	5.80 m <sup>3</sup>		
Small / Medium	4-9m high	13.80 m³	9.20 m³		
Medium	7-10m	21.40 m <sup>3</sup>	14.25 m <sup>3</sup>		
Tall	9-12m0	32.65 m <sup>3</sup>	21.80 m <sup>3</sup>		
Tall & Wide	8m+, canopy 14m+ wide	43.70 m <sup>3</sup>	29.15 m <sup>3</sup>		

### Proposed solutions for the Western Parkland City

#### 2.3.4 Wianamatta street trees – Residential

The challenges present in Western Parkland City cannot be addressed with traditional water sensitive urban design solutions. With consideration of findings from field studies, the following solution seeks to enhance the effectiveness and practicality of water sensitive features in the street verges.

A street tree designed specifically for Western Sydney is recommended to respond to the unique landscape characteristics and address objectives for water management, greening and cooling. The Wianamatta Street Tree is connected to the stormwater system to allow for passive irrigation, optimising tree health and capturing urban stormwater for reuse and nutrient take up. The trees are planted within pits with gravel beds and lining to ensure minimal subsurface infiltration as shown in Figure 21.

#### What is the cost?

The additional cost of the gravel bed and pit components have been estimated at \$2100 per lot. The cost of the street trees itself can be absorbed into the cost of supply and installing traditional street trees to meet canopy targets. Cost-efficiencies could also be created if several trees were planted within the same garden bed with a singular pit. Planting areas: the surface of the raingardens must be densely planted with a variety of plant species. The surface of the raingardens must be at least 100 mm lower than the surrounding areas.

Filter Media: Standard urban soils which support plant growth and has good infiltration capacity. The in-situ infiltration capacity also improve as plants and trees establish complex root networks.

> Gravel Storage Layer: runoff enters the pit and drains into the gravel layer which retains runoff. The trees and plants can access this runoff over a longer period. This layer is lined with plastic liner to prevent salinity issues.

•

Figure 21. Wianamatta Street Tree (1)

Street trees: Placed at variable densities depending on the land use, the trees would ideally be located in bunches to optimise the soil volume available to the trees.



Tree Pits: Allow runoff to flow directly into the drainage layer. The pit is fitted with a coarse filter to remove debris.

### Proposed solutions for the Western Parkland City

# 2.3.5 Wianamatta street trees – Alternative Configuration

For employment areas where pre-screened water is delivered via subsurface pipes – an alternative configuration of the Wianamatta Street Tree is proposed.

Most industrial sites have very large roofs and large areas of hardstand, and often have very low water demands, especially for sites used primarily for warehousing and logistics where water use may be limited to occasional toilet flushing.

For these reasons, it's difficult to minimise runoff using rainwater tanks and pervious surfaces.

Industrial sites are generally very deficient in trees and vegetation, and there's a key challenge in achieving adequate canopy cover. This is particularly important around the Aerotropolis where hotter temperatures have a direct impact on air density and the payload of aircraft.

The default water cycle strategy for the majority of industrial sites therefore uses standard vegetation corridors along the sides and rear boundaries. Subsurface gravel trenches receive runoff from roofs and pavements and provide water to sustain healthy trees. The trenches are to be lined with waterproof membranes to minimise soil reactivity, and all water is pre-screened with 200 micron mesh to maximise longevity.

Further measures to maximise stormwater harvesting on industrial sites include tanks connected to rooftop sprinkler systems which remove stormwater through evapotranspiration and provide evaporative cooling for buildings.



Figure 22. Wianamattta Street Tree (2) - Employment Areas



Figure 23. Wianamatta Street Tree (2) – Detail

#### 2.3.6 Permeable Pavements

There is a broad range of paving technologies that allow water to permeate through a trafficable surfaces. Four main categories of permeable paving are listed below (Eisenberg et al., 2015; Mullaney and Lucke, 2014) and shown in Figure 2424.

- Porous asphalt (PA): Porous asphalt is similar to conventional asphalt, except the fines are removed to create greater void space. Additives and highergrade binders are typically used to provide greater durability and prevent breakdown.
- Pervious concrete (PC): Pervious concrete is produced by reducing the fines in the mix to maintain interconnected void space and has a coarser appearance than standard concrete.
- Permeable interlocking concrete pavement (PICP): PICP is made of interlocking concrete pavers that maintain drainage through aggregate-filled gaps between the pavers. The pavers themselves are not permeable.
- Grid pavement systems (plastic or concrete): Grid pavement systems are modular grids filled with turf and/or gravel. Open-celled concrete or plastic structural units are typically filled with small uniformly graded gravel that allows infiltration through the surface.

Permeable pavements can be designed with under-drainage systems that collect water for reuse or discharge, but more commonly, allow water to infiltrate into the subsoil. They can be designed for a range of traffic loadings, varying from pedestrian foot traffic through to trucks. Like any pavement, poor engineering design that fails to provide adequate structural support for heavy vehicles can lead to uneven subsidence. Useful guidance on structural engineering design of permeable pavements is provided in Eisenberg et al. (2015). Rainfall falling on the surface infiltrates into the voids between the pavement elements, with primary treatment by filtration. Hence, the stormwater is treated at source. They can obviate the need for additional drainage or flood detention systems in urban areas, they hydrate soils in urban environments which may lead to healthier urban tree growth, and they recharge local aquifers.

Permeable pavements are best suited for low traffic loads which are subject to direct rainfall only, rather than receiving runoff from high sediment areas. As such, car parks, driveways, and pedestrian areas are well suited for this technology.

A key risk with permeable pavement is clogging from the sediment they retain, thereby substantially reducing their own permeability. Pervious concrete produces higher permeability and better clogging resistance than porous asphalt, and there are significant gains in permeability and clogging resistance when the porosity is raised beyond 20% (Fwa et al., 2015).

Permeable pavements can reduce the amount of stormwater runoff and pollutants being generated by urban areas, although most studies tend to focus on infiltration responses. For example, average runoff reduction from porous pavements varies between 50% and 93% (Ahiablame et al., 2012).

Boogaard et al. (2014) examined 55 sites located in Netherlands and Australia, which ranged in age from 1 to 12 years old. They tested the Australian systems for a 4 exceedance per year (4EY) storm and found 90% of the pavements performed at this standard. Another study on an 8-year-old permeable interlocking concrete paving system found it to be very effective at filtering and removing sediment from stormwater, with its overall infiltration performance still satisfactory (Lucke and Beecham, 2011).

Bean et al. (2007) undertook a field survey of the infiltration rates of concrete grid pavers, permeable interlocking concrete pavers, and porous concrete. They found that higher surface infiltration rates in concrete grid pavers could be maintained by regular street sweeping. Removing the top layer of residual material (13 – 19 mm) from the larger voids within the concrete grid and replacing it with sand increased infiltration from 49 mm/hr to 86 mm/hr.

There is limited data on water quality performance – although pollutant load reductions would be expected to be commensurate with volumetric load reductions in runoff. In one study, turbidity was reduced (42 - 95%), and effluent measured at <10 NTU for the first three months after maintenance (Sansalone et al., 2012).

Maintenance is essential to achieve long-term permeability in areas with moderate to fine sediment loads. Maintenance by vacuuming or sonication (agitation with sound waves) has been found to restore at least 96% of the initial hydraulic conductivity of clogged permeable concrete pavements (Sansalone et al., 2012). Philadelphia Water (USA) has found vacuuming to be effective in maintaining permeability of porous pavements (Stephen White, Philadelphia Water, pers comm).

Fine clays and silts in stormwater runoff poses a serious clogging risk. Permeable pavers have been shown to be effective in reducing very fine particles (Sansalone et al. 2012), and over time, some of this material accumulates deeper within the subgrade of the pavement and is difficult to remove. Overall, the durability of permeable pavements is moderate – but also is highly context dependent.

	Porous Asphalt	Porous (no fines) concrete	Gap Pavers	Castellated pre-cast pavers with topsoil and turf
Roads	$\checkmark$	$\checkmark$		
Driveways	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
Carparks	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
Laneways	$\checkmark$	$\checkmark$	$\checkmark$	
Courtyards		$\checkmark$	$\checkmark$	
Porous asphalt	Porous (no fines) concrete	Gap pavers	Caste	ellated pre-cast with topsoil and turf

### Table 6. Recommended Minimum Soil Volumes for street trees (ASPECT Studio)



Figure 24. Typical permeable pavement profiles





Figure 25. Permeable pavements come in a variety of forms

#### Key Resource



Eisenberg, B., Lindow, K., & Smith, D. (2015). Permeable pavements . Reston: American Society of Civil Engineers.

Due to the prevalence of combined sewer and stormwater drainage systems in the USA, whereby excess stormwater runoff can lead to sewer overflows, the US has become a leader in permeable pavements.

This publication, by the American Society of Civil Engineers, provides a comprehensive resource for the proper design, construction, and maintenance of permeable pavement systems that provide a transportation surface and a best management practice for stormwater and urban runoff. A cornerstone for low impact development (LID) and sustainable site design, permeable pavements are considered a green infrastructure practice. They offer many environmental benefits, from reduced stormwater runoff and improved water quality to better site design and enhanced safety of paved surfaces. Commonly used for walkways, driveways, patios, and low-volume roadways as well as recreational areas, parking lots, and plazas, permeable pavements are appropriate for many different land uses, particularly in highly urbanized locations.

This volume synthesises today's knowledge of the technology, drawing from academia, industry, and the engineering and science communities. It presents an overview of typical permeable pavement systems and reviews the design considerations. Detailed design, construction, use, and performance information is provided for porous asphalt, pervious concrete, permeable interlocking concrete pavement, and grid pavements. Fact sheets and checklists help to successfully incorporate permeable pavement systems into design projects. Additional chapters summarize emerging technologies, maintenance considerations, hydrologic design approaches, key components for specification writing, and key areas for additional research. Appendixes include a fact sheet clarifying information on common concerns, as well as data tables summarizing water quality treatment performance and costs.

#### 2.3.7 Rainwater Harvesting

Rainwater harvesting is an important component of any stormwater management strategy and can also reduce demand for potable water. Current practice is typically for residential development to incorporate on site rainwater tanks to collect roofwater for reuse in gardens and other non-potable water use. Rainwater harvesting in non-residential development is less common but could offer similar benefits if designed correctly. New technology in rainwater tanks can also lead to improved performance of tanks in managing urban stormwater.

#### Mosquitoes

Rainwater tanks in warm climate areas have been linked to the breeding of the dengue fever vector, the Aedes aegypti mosquito, in rainwater tanks with missing or faulty insect screens (Ritchie et al., 2002 as cited in enHealth, 2004). Some roof material types may be unsuitable for roof water harvesting if there is potential for human ingestion of the collected roof water. For example, roof junctions sealed with lead flashing, or roofs coated in bitumen or treated timber roofs are not suitable for roof water harvesting. Similarly, roof areas subject to discharges from wood burner flues or air conditioning units should also be avoided (Water by Design 2009). More details on managing the chemical and microbiological risks from using rainwater can be found in the IWA rainwater systems book by Sharma et al (2015).

#### Smart Tanks

A recent innovation is the Talking Tanks concept. Developed by lota P/L, the commercial arm of South East Water (a water utility in Melbourne, Victoria), Talking Tanks monitors tank water levels and automatically releases water at a controlled rate, if required. The system allows the release of water from set points that are chosen by the user, according to rain or storm predictions which are received via a web link from the Bureau of Meteorology. The system developers state "The system automatically releases water, creates storage capacity and prevents overflows of stormwater. With unique self-learning, these intelligent systems are paving the way forward for efficient management of rainwater tanks" (for further information see: http://www.iota.net.au/).

The idea of centrally controlled rainwater tank levels have also been successfully deployed in Seoul, Korea (Han and Mun, 2011) as well as in Washington, DC, USA (Quigley and Brown, 2014) to control peak flow discharges from stormwater. Performance of rainwater harvesting systems is highly contextual and influenced by the local climate, the connected roof area , tank size and the actual demands on the water. This can easily be modelled using long-term computer simulation using local rainfall data at either short (sub-hourly) or daily time-steps. See for example the IWA Rainwater book edited by Sharma et al., 2015 (chapters by Vieritz and Neuman and Beal et al.).

As with any distributed technology, end-user uptake and maintenance diligence will be variable, and this should be factored into any planning analyses. For example, a study of 223 detached dwellings in South-east Queensland, Australia, with newly installed rainwater tanks, found only 24% of households complied with the requirement to have at least 50% of roof area connected to that rainwater tank (Biermann et al., 2015).

#### Internal Uses for Rainwater

The stormwater harvesting function was modelled using several assumption of the final configuration. The internal uses were assumed to be limited to toilet flushing, laundry, hot water demands and external irrigation of green spaces on private lots, as shown in Figure 26. Table 7 on page 54 provides the water demands assumed in the analysis.

The model is more sensitive to the fixed daily demands compared to the variable irrigation demands. Rainwater is available to use when there is rainfall and the gardens do not need to be irrigated. This effect is captured in the model.



Figure 26. Rainwater Reuse Internal Demands

	Low-density residential	Medium-density residential	High density residential	Business Park		
Daily rainwater tank demands	0.07	0.07	0.07	0.07		
Toilet demand (kL/d/EP)	0.04	0.05	0.05	0.14		
Laundry demand (kL/d/EP)	0.02	0.03	0.03			
Hot water demand (kL/d/EP)	0.10	0.11	0.11			
EP (EP/Ha)	45	80	200	15		
Total daily demand from tanks (kL/day/Ha)	7.20	14.97	37.67	2.03		
Landscape irrigation from rainwater tanks						
Footprint (ha/ha)	Assun	Assumed 50% of green space on lot is irrigated, not including permeable pavements				
Irrigation Rate (ML/Ha/yr)	1.50	2.50	3.50	5		
Seasonally varying demand from tank (kL/yr)	365	572	771	954		

#### Table 7. Internal and External Water Demands Assumed in Water Balance Modelling

### Industrial

No stormwater harvesting

#### Interaction with Recycled Water

The South Creek corridor will need to consider the impacts of supplying 1 million new residents with water and sewerage infrastructure. Recycled water has been highlighted as a feasible solution to reduce water supply requirements and effluent discharge to South Creek.

By incorporating stormwater harvesting into high-density residential and some commercial developments, the interactions between recycled wastewater and stormwater need to be considered. There are several management solutions to manage interactions. One solution would be that the baseline operation would be during dry periods where recycled wastewater can provide a consistent and reliable water source for supplying dwellings with water for toilet flushing, laundry, hot water and garden irrigation.

During and following rain events, stormwater reuse can be prioritised. Recycled wastewater can be stored and used when the stormwater collected in rainwater tanks has been consumed. Detailed analysis and modelling of recycled water provision for South Creek is still under development. There will be temporal and spatial variance in water usage rates that will need to be considered to determine infrastructure such as regional storage tanks for recycled wastewater and this will be done as precincts are released for development.



Figure 27. Rainwater is prioritised for reuse when available. Recycled water is stored to minimise discharge to waterways.

Figure 28. Recycled water is used when rainwater tanks are empty.

#### 2.3.8 Maintenance

Maintenance has been found to be a significant issue facing water sensitive urban design in many cities. Typical stormwater treatment devices such as GPTs require specific and unrealistic maintenance regimes which are often simply too much for councils to implement.

The strategies that have been proposed aim to keep maintenance to a minimum through well-considered implementation strategies. Such as ensuring the top soil used in the vegetated areas can support healthy plant growth or the "wicking bed" gravel storage which is likely to assist plant survival.

Consistency in the stormwater strategies implemented throughout the city improve efficiency in maintenance. An integrated approach to city-wide landscaping and stormwater management would mean that areas that are already maintained are also areas that manage stormwater. For example, Permeable Pavements would require regular street sweeping to maintain infiltration rates. Street sweeping is already completed in built-up areas to maintain amenity in these areas.

Careful planning and integration of the stormwater strategies in the local governments' maintenance regimes will ensure that the proposed measures are not significant additional burden to the workload of maintenance teams.

#### Naturalised Systems

Naturalised systems used in water sensitive urban design have shown a variable performance in the urban setting. Large, end-of-pipe systems are often difficult to establish and require maintenance access and considerations which significantly increase the foot print of the solution.

Typical maintenance requirement for bioretention systems include:

- Weed management and supplementary planting;
- Litter removal:
- Coarse sediment removal; and
- Periodic flushing of under-drainage.

Maintenance efforts can be minimised by:

- Ensuring there are trees and shrubs in the system to provide shade and help minimise weeds;
- Focussing on the effective establishment of a locally appropriate plant community;
- Ensuring the filter media has adequate organic carbon for denitrification reactions:
- · Organic material in the media to increase water holding capacity;
- Providing a coarse sediment forebay where high sediment loads are expected; and
- Ensuring the system is accessible for maintenance.

Observations have shown that smaller systems, tailored into the urban design, appear to have the best prospects of long-term success as they are likely to receive ongoing maintenance and plant replacement.

#### **Rainwater Tanks**

Regular maintenance of roof water harvesting systems is important to manage water quality (i.e. avoid excessive ingress of organic matter into storage systems from roofs and gutter systems) and mitigate mosquito risk (Moglia et al., 2013). Maintenance should therefore encompass the roof, guttering, leaf-screens, downpipes, tanks, mosquito screens, top up switching valves (to mains water) and pumping systems.

#### Permeable Pavements

Maintenance is essential to achieve long-term permeability in areas with moderate to fine sediment loads. Maintenance by vacuuming or sonication (agitation with sound waves) has been found to restore at least 96% of the initial hydraulic conductivity of clogged permeable concrete pavements (Sansalone et al., 2012). Philadelphia Water (USA) has found vacuuming to be effective in maintaining permeability of porous pavements (Stephen White, Philadelphia Water, pers comm).

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