



ACT
Government

ACT PRACTICE GUIDELINES FOR WATER SENSITIVE URBAN DESIGN

MODULE 1: INTRODUCTION TO WSUD IN THE ACT



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1. INTRODUCTION

Water sensitive urban design (WSUD) is an approach to urban planning and design that aims to integrate the management of the urban water cycle into the urban development process. This includes the management of stormwater to minimise water run-off and ensure that any run-off causes the least amount of damage from a water quality and quantity perspective. It includes the wise use of potable water (i.e. drinking water supplies) and reduction in the generation of wastewater (i.e. water that has been adversely affected in quality by anthropogenic influence. Wastewater can originate from a combination of domestic, industrial, commercial or agricultural activities and is expressed as surface runoff or stormwater) to improve our urban environments.

The ACT Practice Guidelines for WSUD (WSUD Guidelines) continue the ACT Government's commitment to WSUD as part of a broader strategy of responsible water resources management. For example, the ACT Water Strategy 2014–44: Striking the Balance (ACT Water Strategy) sets the strategy for water management in the ACT over the next 30 years. The vision of the ACT Water Strategy is: *“A community working together, managing water wisely to support a vibrant, sustainable and thriving region.”* WSUD is intrinsic to the implementation of the ACT Water Strategy as it encourages reduced mains water use, improved stormwater quality and managed stormwater flows and promotes greywater reuse.

Implementing WSUD is important to the Canberra and region environment because it mitigates the urban impacts on our waterways. WSUD requirements are given effect under the Territory Plan, the key statutory planning document in the ACT, and must therefore be considered at some level in developments. WSUD also provides many benefits to the community.

As Australia's largest inland city, and the largest urban area in the Murray–Darling Basin, Canberra has a proud heritage in high quality water management, which has been refined in the decades since the National Capital Development Commission was responsible for the construction of the city. The 1980s, in particular, saw a change from highly engineered urban waterways to a naturalisation of water management and an increasing appreciation of the merits of natural processes in water quality management. The 1990s saw an increasing emphasis on placing water management responsibility as close to the source as possible (i.e. on block) instead of on the broader catchment or sub-catchment. In the early 2000s, Canberra experienced a severe drought that placed a focus on potable water (drinking water) security.

The Waterways: WSUD General Code (the WSUD Code) is a general code under the Territory Plan, which provides the policy framework for the administration of planning in the ACT and manages land use change and development. The WSUD Guidelines support the WSUD Code by helping to explain the planning provisions set out in the WSUD Code. The WSUD Guidelines provide developers, residents and ACT Government officers with support on introducing WSUD into their urban patch, streetscape, neighbourhood and estate.

The ACT Government previously released a WSUD guideline through the now superseded Waterways 2007 guideline, which was previously codified following the introduction to the new Territory Plan in March 2008. The WSUD Guidelines (2017) are now released for comment following a comprehensive review process involving ACT Government agencies and directorates as well as a technical review panel of industry experts.

The new ACT WSUD Guidelines were revised to support the updated Territory WSUD General Code (2017), which now provides clearer compliance criteria and increased options for complying with the provisions.

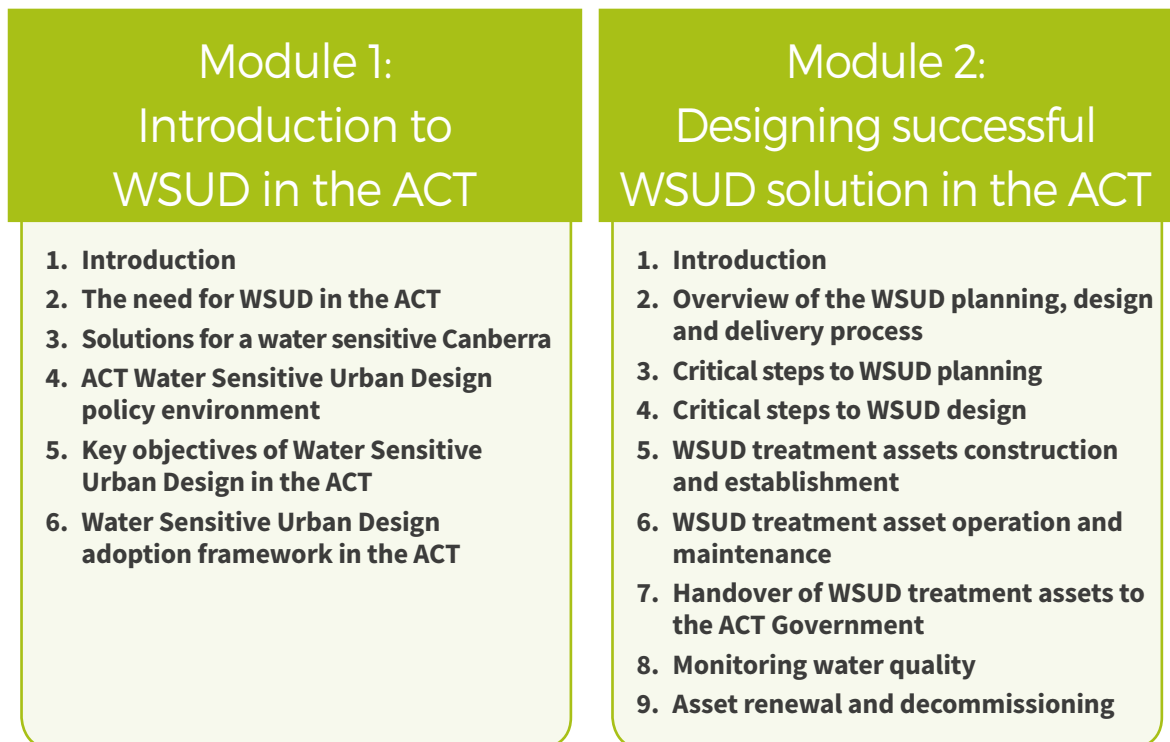
The guideline commentary that is currently contained in the Territory Plan WSUD code is proposed to be removed from the Territory Plan and sit as a standalone guideline. This will mean future updates to the guideline would not need Territory Plan variations.

The ACT WSUD Guidelines is presented as two modules:

- » Module 1—an introduction to WSUD in the ACT— is a newly created ACT WSUD framework document offering a high level review of the ACT regulatory and policy frameworks, and establishing planning principles for the promotion and adoption of WSUD to support ACT Government policies and the Territory Plan.
- » Module 2—designing successful WSUD solutions in the ACT—is a technical practice guideline for WSUD with guidance on how to plan, design and maintain WSUD assets in Canberra, and design checklists and technical references specific to the ACT context.

This set of guidelines and reference documents will support a more cost-effective and efficient adoption of WSUD in the ACT and implementation of the ACT Water Strategy. These documents will also help the ACT Government and urban development industry to work with communities to ensure the planning, design, construction, retrofitting and renewal of urbanised landscapes are more sensitive to the natural water cycle.

Figure 1: An overview of the two WSUD Guidelines documents, outlining the different content provided within each document



Rubble drain in Forde



GPT in Weston

1.1 PURPOSE OF MODULE 1

The ACT Practice Guidelines for WSUD comprises two main documents as outlined in the following figure. The first module provides an introduction to WSUD in the ACT (this document), summarising the need for it and the policy and regulatory framework supporting its adoption.

In Module 1 you will find information relating to the policy context and intent for the application of the WSUD principles in the ACT in relation to the Waterways: Water Sensitive Urban Design General Code. This preamble is primarily intended for policy makers, analysts and town planners. It is also intended for this document to help with the interpretation of policy intent that may be required as part of development approvals by ACT Government officers.

Information contained in this document outlines:

- » the value of WSUD principles in mitigating the impact of urbanisation on the environment and Canberra's lakes, ponds and waterways in particular
- » the importance of WSUD as part of the wider policy framework in sustainable water resources management, land use planning and climate change adaptation
- » how the WSUD policy and practice relate to other initiatives from the ACT Government on climate change adaptation, living infrastructure policy and water quality improvement
- » the expectations from the ACT Government for the application of WSUD to greenfield developments, urban renewal projects and transport infrastructure
- » the relative importance and specific targets and objectives that future developments will be expected to comply with across a range of water management issues and pollutant types.

Figure 1 represents the chapters and content.

Scientists, engineers and WSUD practitioners will find more details and specific information in Module 2 of the ACT Practice Guideline for WSUD.

Civic raingarden



2. THE NEED FOR WSUD IN THE ACT

WSUD has been trialled and adopted in the ACT since 2005 to better protect our urban waterways, lakes and ponds and ultimately contribute to a more sustainable urban community. The historical approach to urban water management of relying on conventional ‘pits and pipes’ drainage solutions and typical provisioning of water and sewerage services is recognised for creating a number of challenges and issues for the long-term health and integrity of our waterways.

The typical negative impacts of urbanisation on the urban water cycle and waterways are presented in Figure 2 and discussed in more detail in following sections.

2.1 IMPACT OF URBANISATION

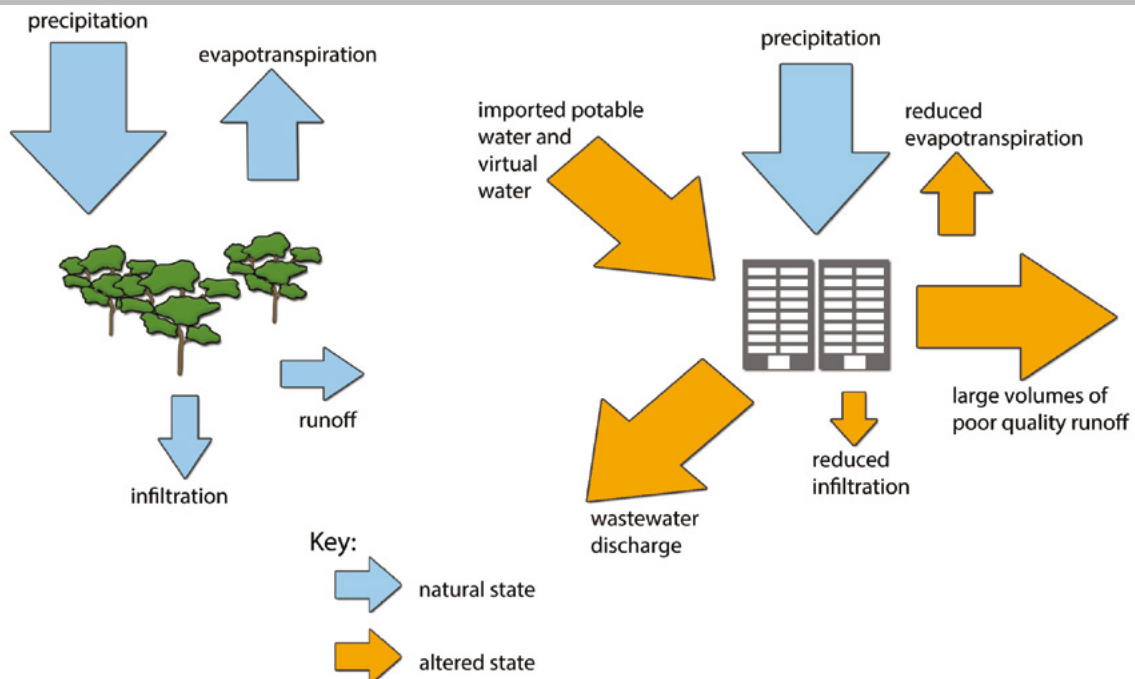
As our city grows, more urban areas need to be developed to supply the demand for housing from a growing population. This urbanisation of the ACT natural catchments has been identified as having significant impacts.

2.1.1 Urban catchment hydrology

In well vegetated, undeveloped catchments, the majority of the small, frequent rainfall events are absorbed by catchment soils and vegetation and do not produce surface run-off. When these catchments are urbanised, the water cycle changes dramatically (Figure 2).

The increased impervious areas in urban environments (such as roofs, roads, parking lots, driveways) reduces evapotranspiration and infiltration, which results in higher volumes of surface run-off being generated and transported directly to receiving waters in a pipe network. Additional impacts to the receiving environments also result from the discharge of treated wastewater from treatment plants into waterways.

Figure 2: The water cycle comparison for natural areas (left) and urban areas (right) showing key changes in imported flows, evapotranspiration, infiltration and run-off/discharges (Hoban and Wong, 2006)



The resulting changes in stormwater flow events (both in magnitude and frequency) deliver urban pollutants and disturb in-stream ecosystems (e.g. Walsh 2000). These changes have been shown to have a strong correlation with the degradation of receiving waters, such as streams and lakes.

Two factors driving this increase in stormwater flow events are: the increase in imperviousness and the hydraulic efficiency of our conventional drainage infrastructure.

Imperviousness is the source of most problems

With increasing impervious areas (such as roofs, roads, parking lots, driveways) in urban areas, the natural processes of infiltration and evapotranspiration are substantially reduced. During storms, rain that previously would have infiltrated the soils now runs off impervious surfaces into the stormwater system. This in turn reduces the recharge of groundwater systems and base flows in creeks.

Conventional drainage does not meet modern expectations

To manage the increased surface run-off, conventional drainage solutions have relied on increasing the hydraulic capacity and effectiveness of drainage infrastructure with smooth concrete or plastic pipes, concrete floodways and other drains that can efficiently, rapidly and cost effectively convey flows away from assets and people. Until the 1990s, this approach met the expectations of our community by reducing nuisance flooding, protecting lives and properties. Since the 1990s the growing public awareness of environmental issues has highlighted the effect on receiving waters, the degradation of urban waterways, the gradual worsening of flash flooding downstream and loss of ecosystem function and values.

2.1.2 Water quality

Compared to natural catchments such as forests or rural areas, urban areas typically generate pollutants at a greater rate, from both stormwater and wastewater discharges.

The range and quantum of pollutants associated with human activities, economic activity, cars and other vehicles are significantly greater.

Three factors explain these observations:

- » a higher generation rate of pollutants (from metal roof areas, vehicle wear, littering in urban areas and general corrosion of urban infrastructure)
- » a greater mobilisation of the pollutants via the efficient drainage infrastructure that prevents the natural trapping of these pollutants by the plants and soil of undeveloped catchments
- » Stormwater quality is a fairly complex and well documented matter (Engineers Australia, ANZECC Guidelines), but it can be simplified in a range of:
 - physical parameters: turbidity, preventing the penetration of light that sustains ecosystems in water bodies and smothering aquatic habitats; temperature; acidity/pH; electrical conductivity and salinity
 - biochemical parameters: increased concentration of nutrients, oxygen demanding material
 - micro-organisms and toxic pollutants including heavy metals, pesticides, hydrocarbons, microbes, bacteria.

These pollutants may impact immediately due to their presence in the water column, but also have the potential to settle and accumulate in sediments creating a long-term threat to ecosystems and food chains.

2.1.3 Impact on receiving water ecology and geomorphology

In addition to the pollution challenges, ACT waterways are also directly affected by the increase in stormflow events. Erosion and changes to the morphology of creek beds and banks commonly lead to loss of ecosystem function and habitat values. The material eroded from streams typically settles and accumulates in lakes and ponds, where habitats become degraded.

In Canberra, as elsewhere, the impacts and challenges for waterways and creek systems are different from those for urban ponds and lakes.

Waterways and creeks

For waterways and creeks in natural catchments, the buffering capacity of the catchment through infiltration and evapotranspiration means less water enters the creeks as surface flows and the frequency of creek flooding is less than in urban catchments for a storm event of a given size. Less frequent disturbances means the waterways and creek ecosystems have time to re-establish and recover.

In urban catchments, the intensity and frequency of storm flows are high enough for systems to be impacted in many ways, including:

- » erosion and scour of banks (widening of channels)
- » loss of habitat by scouring away of cobbles, woody debris and other habitat supporting elements
- » increased algal growth due to the more prevalent availability of light because of lost vegetation
- » loss of aquatic fauna and organisms, except for a select few species that resist higher flows
- » decreasing levels of dissolved oxygen concentration.

Management of healthy waterways and creeks requires the protection of the geomorphic and ecosystem integrity, primarily by focusing on frequency of disturbance, intensity of disturbance and frequency of stormflows. Rehabilitation work in streams may only succeed if catchment-scale impacts have been addressed.

Lakes and ponds

These water systems are quite different from waterways and creeks because of their large buffering capacity. They are less subject to the frequent disturbance that impacts waterways and creeks. The most concerning issue for lakes and ponds is the accumulation of pollutants, nutrients and sediments in the water body. Degrading water quality and loss of amenity and ecosystem integrity is commonly noticed after many years of accumulation. This means that restoring lakes and ponds can be quite complex and expensive. Management of lakes and ponds needs to focus on nutrient and sediment loads and have long-term objectives.

2.2 EVIDENCE OF THE PROBLEM

2.2.1 Increasing concern for water quality in Canberra's lakes and ponds

In recent years, work carried out by the ACT Government through water quality monitoring and predictive modelling of water quality in Canberra's lakes and ponds has revealed an accumulation of common nutrients (nitrogen and phosphorus).

In addition, the community engagement informing the review of the WSUD General Code revealed a growing concern amongst catchment groups, scientists, practitioners and Canberrans for the decreasing quality of water in our ponds, lakes and waterways. The Social Expectations Survey of the ACT and Region Waterways conducted by the University of Canberra in 2015 also found that understanding of the threats to water quality is relatively low. Therefore it is important to convey a clear message of the benefits of WSUD.

2.2.2 Community expectations and government action to remediate the problems

In responding to the community expectations regarding the preservation of high amenity values associated with Canberra's lakes and ponds, the ACT Government is also reacting to the conclusion of the CSE report: 'unless there is effective action, threats are expected more severe into the future'.

In aligning the policies, including these WSUD Guidelines, with the ACT Water Strategy 2014–2044: Striking the Balance, and progressing with the ACT Healthy Waterways Project, the ACT Government is demonstrating its commitment to improve the long-term health of ACT waterways.

Detention basin in Harrison



3. SOLUTIONS FOR A WATER SENSITIVE CANBERRA

3.1 WSUD IN THE ACT

In response to the many challenges associated with conventional drainage solutions, the concept of water sensitive urban design emerged in the 1990s. WSUD placed a focus on the interconnection between land-use planning, urban planning and design and the impact on urban streams at the centre of a new approach.

It marked the latest evolution of modern water management in cities that first emerged as municipal sanitation programs in the late 19th century, when cities constructed extensive sewer systems to help control outbreaks of disease such as typhoid and cholera. This evolution over the last 130 years revealed the gradually increasing scope for water management in cities, now including sewerage and sanitation, potable water supply, stormwater drainage and flood mitigation, non-potable water supply and stormwater quality control.

The application of the WSUD principles in the ACT can reduce the common impacts of urbanisation on the water cycle (Figure 4). One key impact of urbanisation is that excess water (run off) is generated, leading to more water, rather than less, being delivered to urban streams. WSUD helps to manage urban stream environmental flows through a range of strategies such as stormwater harvesting.

WSUD strategies should aim to mimic the natural water cycle in urban environments by:

- » reducing the amount of stormwater run-off generated (reducing impervious areas)
- » reducing the amount of imported water (using local water sources such as harvested and treated rainwater, stormwater and wastewater)
- » reducing the amount of wastewater generated (water conservation)
- » reducing the amount of polluted water entering the waterways (treatment and re-use of wastewater and stormwater).

Figure 3: Water sensitive city journey (Brown et al, 2009)

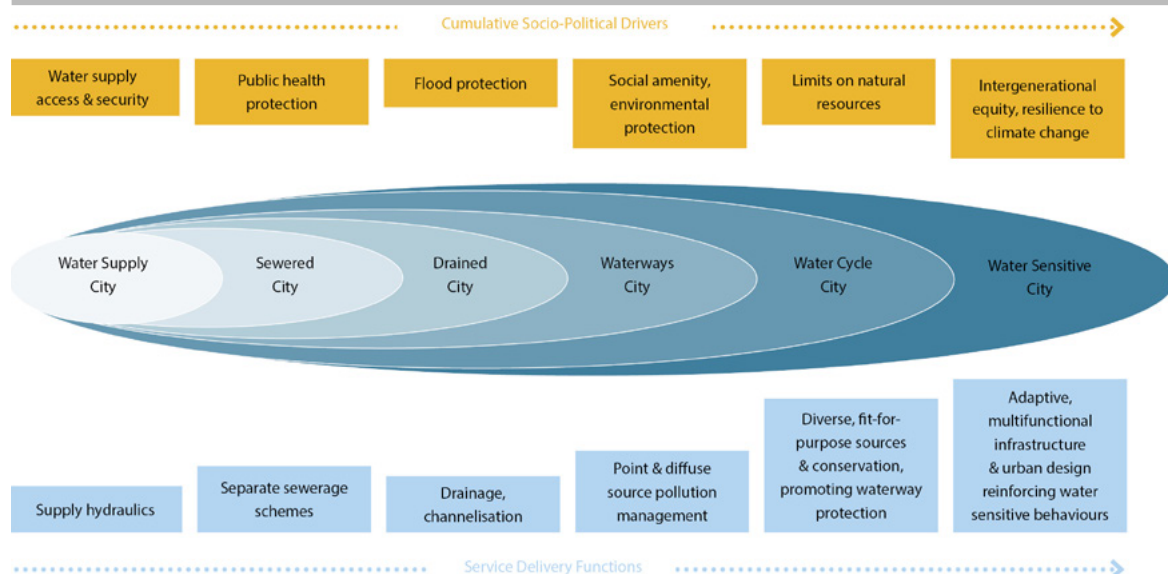
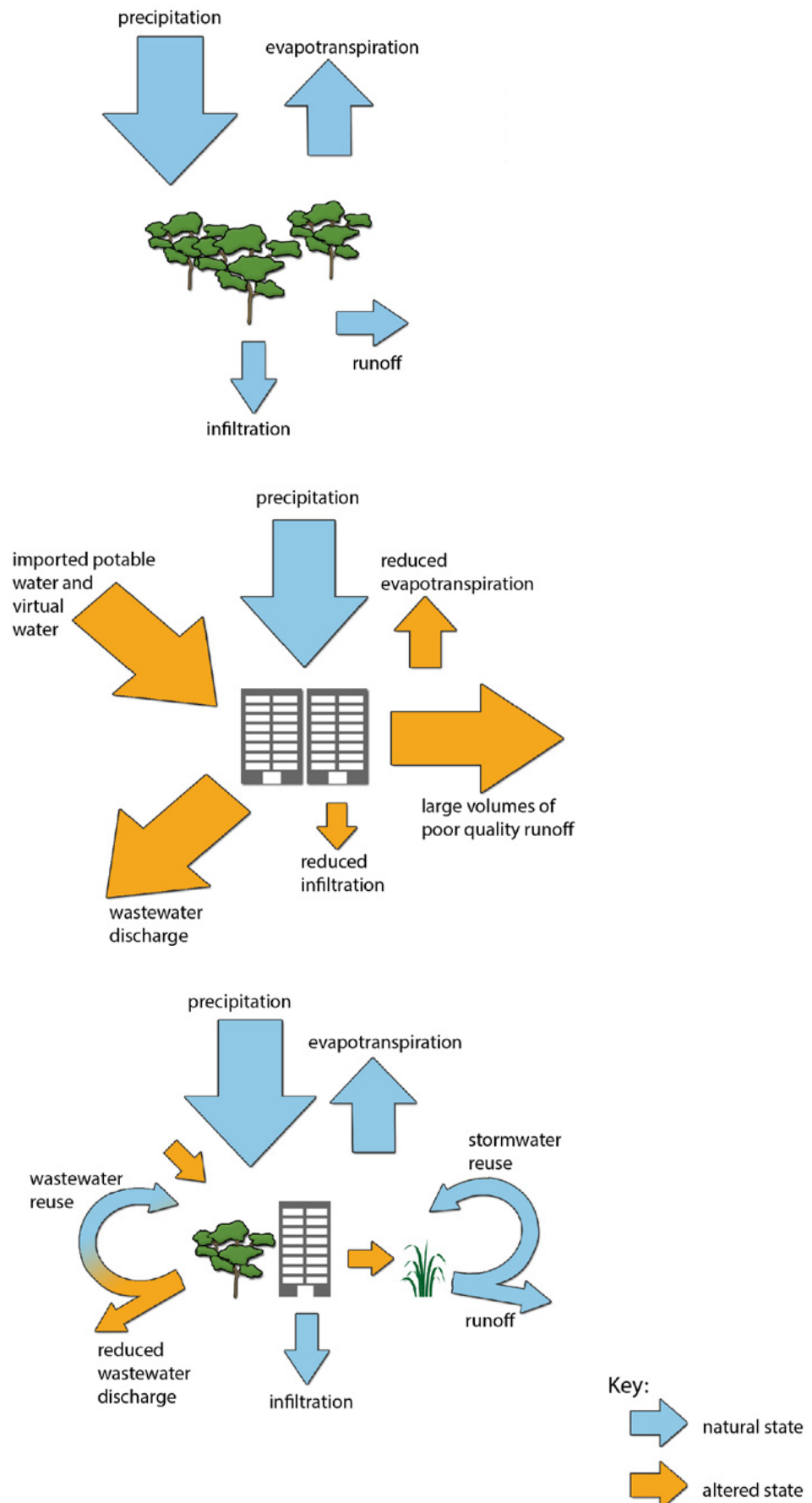


Figure 4: The water cycle comparison for natural areas (top), urban areas (middle) and urban areas incorporating WSUD (bottom) shows key changes in imported flows, evapotranspiration, infiltration and run-off/discharges (Hoban and Wong, 2006)



To ensure WSUD is effectively and efficiently delivered in the ACT, the following principles should be considered:

1. Identify and consider the type and condition of the receiving waters.
2. Focus on addressing the causes of the hydrological imbalance first.
3. Preserve existing public and private assets such as potable water and stormwater networks.
4. Promote the integration of WSUD as part of the broader green infrastructure and environmentally sustainable design principles.
5. Identify fit-for-purpose use of all urban water sources.
6. Create stormwater treatment trains and match solutions to pollutant types.
7. Keep stormwater assets simple and cost effective wherever possible.

These principles are described in more detail in the following sections.

3.1.1 Consider the receiving waters

Located two hours from the nearest coast, water bodies in the ACT have a particular value. Preserving the water quality and the associated amenity values in Canberra is about more than good environment management. Many families rely on the creeks, waterways and urban lakes and ponds for recreational purposes and relief during summer in particular.

The potential impacts of urbanisation on flowing and still receiving waters differs. It is therefore important to develop a WSUD strategy that reflects this.

Flowing water systems

Flowing water systems (i.e. waterways or creeks) can be either ephemeral (occasionally dry) or perennial (permanent water).

Table 1: WSUD strategy requirements for Flowing (creeks and waterways) systems identifying the difference between ephemeral and perennial waterways

Waterways	WSUD strategy requirements
Ephemeral	These headwater streams will become much wetter when the catchment is urbanised. It is therefore important to try and reduce frequent flow events and ensure constant wastewater discharges do not occur.
Perennial	Increasing the volume and frequency of stormwater run-off events increases the risk of bed and bank erosion in freshwater streams. Channel forming flows (1.5–2 year Average Recurrence Interval (ARI) flows) should be managed to reduce waterway stability impacts.

Still water systems

Designing and managing lakes and ponds needs to focus on reducing pollutant loads entering the water column and the time it takes for water to pass through the water body (i.e. residence time). Specific design considerations include:

- » water quality of the inflows (poor water quality will result in a build-up of nutrients in the system, which can result in algal blooms)
- » carbon loads (high volumes of floating plants can provide a continuous supply of carbon, which can deplete the oxygen in the water and release nutrients when it decomposes)
- » mixing of the water profile (deep lakes can experience stratification, which leads to low oxygen levels and release of nutrients from the sediments)
- » Residence times (large systems which are not flushed by catchment flows regularly have an increased risk of algal blooms).

3.1.2 Preserve existing public and private assets

When WSUD is incorporated into new developments, it can protect the function of existing public and private assets including existing water and drainage networks. WSUD can preserve these existing assets by:

- » reducing potable water requirements by using alternative water sources for appropriate demands
- » slowing and detaining stormwater flows, which attenuates peak flows entering the stormwater network, reducing nuisance flash flooding
- » providing resilience to urban areas given predicted climate change impacts of more intense storm events.

Strict consideration of the potential impact of a development's stormwater flows on conventional drainage and existing assets in compliance with MIS 08 Stormwater is required.

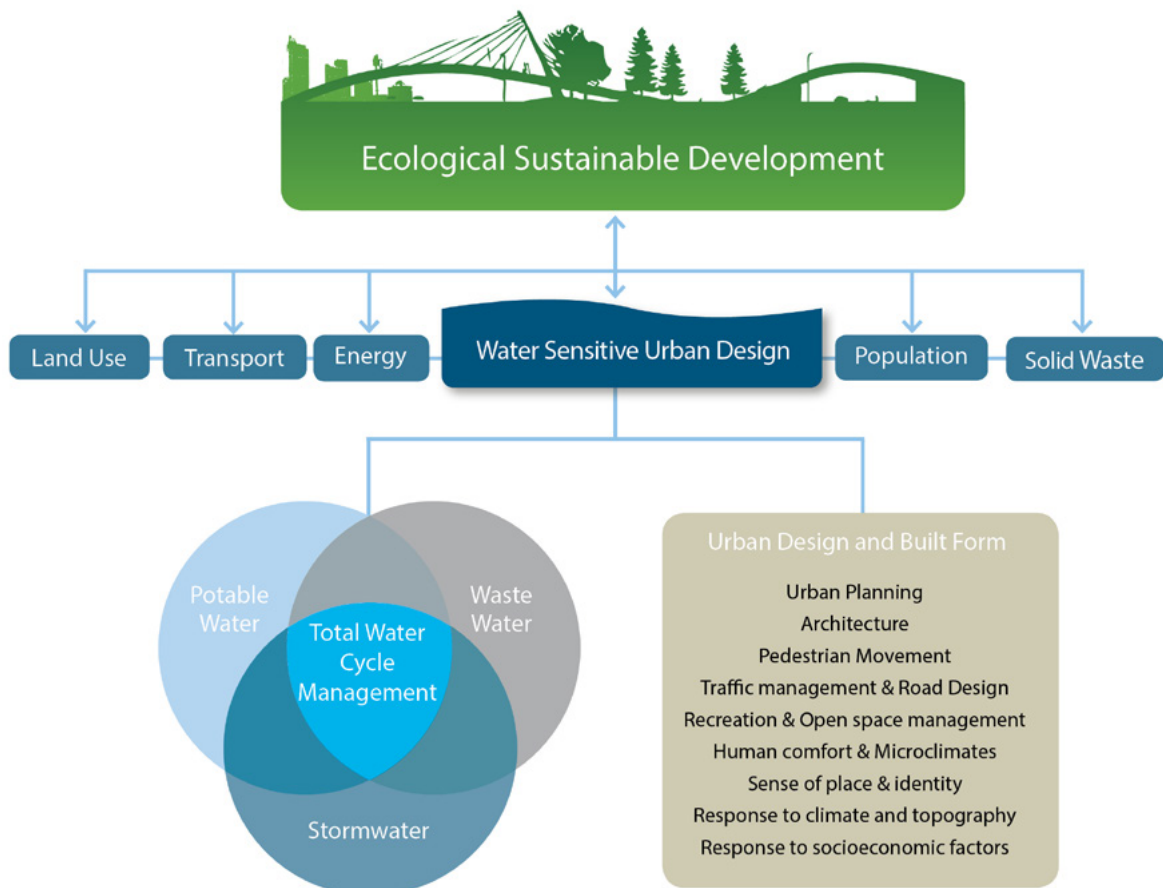
3.1.3 Promote the integration of WSUD as part of the broader living (green) infrastructure and environmentally sustainable design

WSUD brings together integrated water cycle planning and urban design and planning and should be considered early in projects as a layer in the delivery of environmentally sustainable development (refer Figure 5). This integration of sustainable water management and the urban landscape also supports the delivery of resilient green infrastructure which can help to deliver multiple benefits including sense of place, microclimate and human comfort, stormwater treatment and potable water reduction.

Integration with public realm and public open spaces planning

The successful planning and design of public realm and open spaces will manage competing outcomes in the most effective manner to achieve multiple functions in these important urban green spaces.

Figure 5: WSUD brings together total water cycle management and the design of the urban built form to contribute to environmentally sustainable development (Hoban and Wong, 2006)



The following design principles based on the Concept Design Guidelines for WSUD (Water by Design, 2009) should be used to guide the integration of stormwater management devices within public open spaces:

- » Maximise the amenity and use of open space areas by ensuring that the footprint of stormwater management device should not take up more than 50% of the available open space area.
- » Sit the stormwater management device seamlessly with the surrounding landscape setting and design it to maximise the visual interest and amenity.
- » Locate stormwater management devices along waterway corridors away from flood flows and depths capable of impacting performance.
- » Wherever possible, retain or revegetate areas with locally endemic plant species.
- » Investigate opportunities to collect stormwater for re-use for irrigation or public water features.

Integration with urban design and built form

There are many opportunities to incorporate WSUD solutions within the built form to provide multiple benefits. These opportunities include:

- » reducing potable water requirements of buildings by using water-efficient fittings and appliances and fit-for-purpose re-use of alternative water supplies (such as rainwater, stormwater and wastewater)
- » reducing water discharged from a site by:
 - reducing stormwater run-off by using permeable surfaces such as porous pavements and green roofs
 - treating and harvesting rainwater, stormwater or wastewater on-site for uses such as toilet flushing and garden and green wall irrigation
- » improving local microclimates and reducing urban heat island impacts with the use of green infrastructure such as green walls and street trees, which retain water in the soil and support healthy plant growth.

Appropriate solutions will need to be developed in close partnership with project planners, architects and landscape architects, on a case by case basis.

3.1.4 Fit-for-purpose water use

Many alternative sources of water can be used in urban developments to reduce potable water use and reduce the volume of wastewater and stormwater discharged from the site. Any source of alternative water can be used for any purpose; the issue is the amount of treatment and the associated regulatory complexity. Based on minimising the amount of treatment required and considering regulatory complexity, a fit-for-purpose approach can be used to match potential supply to demands. This approach considers the risk profile of the water demand and ensures the water source is suitable for this end-use, reducing the risk to the end-user but also ensuring the water is not over-treated, which can be costly. Table 2 presents the fit-for-purpose framework which can be used to inform integrated water cycle solutions.

Table 2: Fit-for-purpose water use framework identifying the preferred uses for all urban water sources

Source	Demand							
	Irrigation	Kitchen		Laundry		Toilet	Bathroom	
		Cold	Hot	Cold	Hot		Cold	Hot
Mains water	3	1	2	1	2	3	1	2
Wastewater								
Treated effluent	2	4	4	4	4	2	4	4
Greywater	1	4	4	4	4	1	4	4
Stormwater								
Roofwater	2	2	1	1	1	2	2	1
Non-roof water	2	4	4	4	4	2	4	4

1 = preferred use, 2 = compatible use, 3 = non-preferred use, 4 = not compatible

Source: Landcom WSUD best planning and management practices (2004)

Create stormwater treatment train and match solutions to pollutant types

A stormwater treatment train is a combination of stormwater treatment devices that together address the range of pollutants found in stormwater by using a range of treatment processes. Rainwater tanks, while not strictly a stormwater treatment device, provide a mechanism to capture and reuse roof water to reduce the volume of stormwater that needs to be subsequently treated. Rainwater tanks can therefore be the first element in a stormwater treatment train. Similarly, stormwater harvesting (e.g. from a pond) can reduce the volume of stormwater entering the downstream receiving environment.

Where stormwater harvesting systems are incorporated, they are typically the last element of a stormwater treatment train, to ensure the quality of the stormwater is suitable for the connected end uses. The sections below focus on stormwater pollutant removal processes to inform the development of treatment trains after any initial roof water harvesting and prior to stormwater harvesting and reuse.

Mechanisms of pollutant removal

Different treatment processes are required to remove the wide range of pollutant types and sizes in stormwater. Processes include screening of solids, sedimentation of coarse to medium sediments, adhesion of very fine and colloidal matter, sorption and biological uptake of dissolved nutrients (Figure 6).

Figure 6: Stormwater pollutant sizes, associated management issues and treatment processes required to remove the pollutant and address the issues effectively (Ecological Engineering, 2003)

Particle Size Grading	Management Issues					Treatment Process
	Visual	Sediment	Organics	Nutrients	Metals	
Gross Solids >5000 μm	Litter	Gravel	Plant Debris			Screening
Coarse to Medium 5000 μm - 125 μm						Sedimentation
Fine Particles 125 μm - 10 μm		Silt		Particulate	Particulate	Enhanced Sedimentation
Very Fine / Colloidal 10 μm - 0.45 μm	Turbidity				Colloidal	Adhesion and Filtration
Dissolved < 0.45 μm			Natural and Anthropogenic Materials	Soluble		Biological Uptake

Figure 7: Stormwater treatment measures and the treatment processes they provide can remove different pollutant types and sizes (Ecological Engineering, 2003)

Particle Size Grading	Treatment Measures						Treatment Process
Gross Solids >5000 μm	Gross Pollutant Traps						Screening
Coarse to Medium 5000 μm - 125 μm		Sediment Basins	Ponds				Sedimentation
Fine Particles 125 μm - 10 μm				Grass Swales and Buffers	Non-Vegetated Infiltration Systems	Wetland	Enhanced Sedimentation
Very Fine / Colloidal 10 μm - 0.45 μm						Bio-retention	Adhesion and Filtration
Dissolved < 0.45 μm							Biological Uptake

Stormwater treatment train

Different stormwater treatment devices are effective at removing different pollutants, from screening of gross pollutants through to biological uptake of dissolved nutrients (Figure 7).

The order of the treatment systems in a treatment train should target gross pollutants first so following treatment systems can target fine particles and dissolved pollutants more effectively. For example, a bioretention system will work more effectively if it is located after a coarse sediment removal system. Note, urban catchments typically transport more sediment (in stormwater) than natural forested catchments. The typical treatment train is therefore designed to trap the enhanced sediment transport resulting from urban catchments. The addition of high flow by-passes (e.g. the high flow by-pass on a constructed stormwater treatment wetland) allow the transport of medium sized particles (silts and sands) during high flow events. Coarse sediment transport to waterways during infrequent high flow events is a natural and important waterway process.

A typical stormwater treatment train often adopted in Canberra is shown in Figure 8. There is the potential to harvest the treated stormwater from the pond for reuse.

Figure 8: Typical stormwater treatment train adopted in Canberra



3.1.5 Keep WSUD assets simple and cheap wherever possible

An important design principle to adopt is to eliminate complexity, reduce moving and mechanical parts and work with gravity in order to:

- » reduce costs
- » limit possibilities for structures to fail
- » increase resilience to extreme events.

Three main focus areas to achieve this are:

1. using gravity
2. reducing complexity
3. addressing blockage risk.

These are described below in more detail.

Use gravity systems

There are circumstances where using pumps may offer significant advantages and may be appropriate but, in most instances, pumps should be avoided to:

- » reduce capital costs
- » reduce operating costs
- » lower carbon emissions.
- » reduce maintenance costs
- » reduce energy consumption

Reduce hydraulic structure complexity

As much as possible, designs should rely on typical structures as outlined in MIS 08 Stormwater or previously accepted by Transport Canberra and City Services Directorate (TCCS) and proven to operate adequately. Where hydraulic constraints dictate, complex structures may be appropriate but should be discussed with TCCS.

Blockage/fail safe solutions

Given the variable nature of pollutant loads, there is a possibility for inlets, outlets and other hydraulic structures to fail. Part of the design process requires testing the impact of blockage to prove the adequate operation of structures in failsafe conditions.

The seven key design principles described in this section should be considered throughout the development of WSUD strategies to ensure the solutions are effectively and efficiently delivered in the ACT. The following sections provide an overview of how these strategies should be developed and delivered.



3.2 SCOPE OF APPLICATION

WSUD principles are to be applied consistently across the many different development types.

As the application of WSUD is required more broadly, it is important that the objectives be adjusted to reflect the constraints and opportunities associated with each major development type, as identified below.

3.2.1 Greenfield development

Greenfield developments transform relatively undeveloped land (e.g. natural areas or rural lands) into urban land uses. The key WSUD objective for greenfield development is to influence the urban fabric structure during planning and design. The strategic urban fabric in greenfield developments sets the trajectory for the long-term performance of the new urban communities.

Consequently, the priorities in such developments are:

- » providing adequate public open space
- » influencing the location and planning of road networks
- » adjusting the WSUD infrastructure to reflect the specific conditions and constraints of each catchment
- » influencing the connectivity between public land and private lease open spaces
- » supporting the inclusion of considerations for urban heat island and climate change in the conception of urban infrastructure.
- » developing solutions at neighbourhood scale.

Greenfield developments are the most typical application of the ACT WSUD Guidelines and WSUD Code. They also offer the most diverse range of solutions. The WSUD strategy can leverage the best possible flexibility and relative absence of infrastructure constraints compared to the other development types.

Accordingly, with the highest degree of flexibility and lowest constraints, greenfield developments are not intended to be eligible for exemptions or offset of the WSUD requirements (see section 3.2.5 below).

3.2.2 Redevelopment and urban infill projects

Urban renewal and redevelopment projects form a significantly increasing portion of urban development projects in the ACT. While the ACT Government always considered urban renewal projects would contribute to achieving the Territory's objectives for WSUD, the objectives and WSUD framework for urban renewal projects were poorly defined.

The importance of defining cost-effective and flexible WSUD solutions in urban infill projects is reflected in this section.

In urban infill projects, the adoption of WSUD principles is limited or constrained by the presence of existing infrastructure. The three key consequences are:

- » All proposed WSUD infrastructure needs to take account of infrastructure constraints in terms of outlet points and infrastructure capacity.
- » WSUD strategy and infrastructure may attract a higher cost than greenfield developments and any proposed infrastructure needs to be carefully considered in terms of benefit/cost.
- » Frequently, the developments will be constrained by the legacy of historical planning. Opportunities for larger scale solutions may be limited.

Consequently, the priorities in most developments are:

- » the adoption of identical targets as greenfield developments wherever possible to progressively improve water quality discharged from existing urban areas as part of the urban renewal process
- » to achieve a net reduction in directly connected imperviousness compared to existing development conditions
- » to maintain or improve the capacity of stormwater drainage networks (in terms of flooding)
- » to manage wastewater in a manner which responds to local sewer and treatment plant capacities, such that infrastructure upgrades are avoided
- » to achieve a net improvement in water quality outcomes.

In instances where achieving these priorities may prove technically impossible or represent prohibitive costs, there is the potential for projects to participate in a WSUD requirements offset scheme when developed and implemented in the ACT.

3.2.3 Transport infrastructure

The incorporation of WSUD into transport infrastructure can prove particularly challenging from a stormwater management perspective due to the linear and elongated nature of development.

The WSUD strategy for transport infrastructure projects should:

- » apply the standard targets wherever possible
- » maximise all opportunities for WSUD in verges and medians
- » reduce impervious areas wherever possible, such as parking bays
- » look for opportunities outside of the transport corridor
- » offset residual impacts.

3.2.4 Low impact developments and developments downstream of natural catchments

The framework and targets in the WSUD General Code aim to mitigate the impact of common urban development types. Situations where the strict application of these targets may lead to expensive and unnecessary infrastructure include, in particular:

- » low impact development
- » low density development
- » developments located downstream of natural hills and ridges.

For such situations, a framework for adjusting the applicable targets has been developed. The reduction in developer targets reflects the natural loads generated in natural catchments and is based on:

- » proposed urban imperviousness (%)
- » percentage of total catchment zoned 'urban'.

Refer to Appendix A of Module 2 for the Catchment-wide Reduction Targets Framework.

3.2.5 Offsetting WSUD requirements

The intent of a WSUD offset scheme is to provide:

- » A mechanism whereby the ACT Government provide flexibility for developers in lieu of delivering on-site WSUD solutions. A contribution is paid and used to implement regional WSUD solutions that deliver an equivalent or greater benefit at lower cost. In principle, offsets are limited to developments where on-site stormwater management is highly constrained and where all other feasible and cost effective measures to avoid and mitigate on-site impacts of development have been exhausted.
- » A mechanisms whereby the developer can offset an equivalent volume of stormwater (for stormwater quantity management) or equivalent load of pollutants at an off-site location as part of a stormwater offset agreement with the ACT Government.

No WSUD offset scheme is currently available in the ACT. The superseded version of the Waterways: WSUD General Code (2009) provided a clause to facilitate an offset, stating

“in such cases it may be possible, with the approval of the Authority, for the developer to consider a contribution to the construction of off-site measures as a means of offset.”

However, no scheme was developed.

The introduction of an offset scheme requires careful planning to develop strategies for the collection and acquittal of offset funds including:

- » the identification of catchments where offsets may apply, informed by total water cycle and catchment planning (including receiving water condition and rehabilitation potential)
- » the identification and costing of offset projects
- » determination of the offset scheme pricing (typically based on infrastructure total life cycle costs including land costs, CAPEX, OPEX, planning, design, construction, establishment and administration)
- » a transparent method of reporting on the outcomes and benefits delivered through the offset scheme.
- » The ACT Government will continue to work on developing an offset scheme; however, in the interim the ACT Government must be consulted about any offset scheme proposal prior to the development application being lodged. Each application will be assessed on its merits on a case-by-case basis.

3.3 HOW WILL THE ACT COMMUNITY BENEFIT FROM WATER SENSITIVE URBAN DESIGN?

Water sensitive urban design can provide multiple benefits to the ACT community including:

- » healthy water environments, with less water pollution
- » resilient green landscapes which are irrigated by non-potable sources
- » cooler urban areas created by keeping water and vegetation in built up areas, reducing urban heat island effects
- » improved urban habitat and biodiversity by retaining and using native vegetation
- » improved urban amenity and social interaction
- » reduced nuisance flooding by detaining and treating frequent flows within the catchments.

3.4 KEY RISKS AND UNCERTAINTIES ASSOCIATED WITH WATER SENSITIVE URBAN DESIGN

Water sensitive urban design can present a number of risks when the design and maintenance of stormwater assets are not undertaken adequately, including:

- » nuisance weed growth
- » poor plant establishment in vegetated stormwater assets
- » poor amenity associated with litter, sediment and weeds in stormwater assets
- » variable performance outcomes
- » increased maintenance costs.

Module two of these guidelines provides the necessary information to mitigate these risks in the future.



4. ACT WSUD POLICY ENVIRONMENT

4.1 NATIONAL POLICY CONTEXT

4.1.1 Murray–Darling Basin Plan

The Murray–Darling Basin Plan 2012 (Basin Plan) is a major water resource plan that affects the ACT in water-related matters including WSUD. The Basin Plan provides a high level framework that sets standards for the Australian Government, Basin states (including the ACT) and the Murray–Darling Basin Authority to manage the Basin’s water resources in a coordinated and sustainable way in collaboration with the community.

In 2012, the ACT and other Basin states accepted a limit on the maximum volume of surface water that can be diverted from each river system of the Murray–Darling Basin annually under the Murray–Darling Basin Agreement. This abstraction limit is fixed, regardless of the amount of water available in the river system or the capacity to store water (in dams, lakes etc.). This limit is referred to as the ‘Cap’. Under the Basin Plan, from 2019 all Basin states are required to operate under a sustainable diversion limit (SDL), which will replace the Cap. The SDL will be 40.5 gigalitres (GL). The Basin Plan will be reviewed in 2022.

Unlike other states, the ACT uses ‘net’ abstractions to account for water use. That is, the ACT’s SDL includes water abstracted and returned to the river, rather than just abstracted. For example, if the ACT abstracts 50 GL from its water resources but returns 30 GL to the Murrumbidgee River (following treatment at the Lower Molonglo Water Treatment Plant), its ‘net’ abstraction is 20 GL. The diversion cap has relevance for any large-scale harvesting.

The Basin Plan requires the ACT to have a water resource plan and a water quality plan. Through these plans, WSUD has an important role to play in our commitment to the Basin Plan in identifying alternative water sources to supplement river extractions and helping continue to protect water quality in the ACT and downstream, and help ensure there is no net decline on river health in the Basin.

4.1.2 ACT Healthy Waterways (Basin Project)

On 26 February 2014, the ACT Government signed a funding agreement, in the form of a Project Schedule to the Water Management Partnership Agreement (WMPA), for the ACT Healthy Waterways (Basin Project). The WMPA is between the Basin States and the Commonwealth to undertake water reforms in the Murray–Darling Basin.

The agreement provides for funding of up to \$85 million and is aimed at ‘improving the long term water quality in the ACT and the Murrumbidgee River System’.

ACT Healthy Waterways will contribute to achieving positive outcomes for the Canberra community through improvement in water quality in its lakes and waterways. It will also provide significant downstream benefits through improving water quality below the ACT in the Murray–Darling Basin. Improving water quality will have benefits not only for the environment, but also for the community through the social and economic contribution of lakes and waterways to the region.

Phase 1 of this project focused on implementing a comprehensive water quality monitoring program and assessing a range of potential options to improve water quality.

Based on the collected data, phase 2 involves the development and construction of infrastructure in six priority catchments that will help improve the water quality flowing from these catchments. ACT Healthy Waterways is expected to be completed by 30 June 2019.

The information gathered from ACT Healthy Waterways will assist in the understanding of WSUD assets and infrastructure and how they operate within our catchments.

4.1.3 National Capital Plan

Planning within the Territory is guided by the Australian Government through the National Capital Plan, administered by the National Capital Authority (NCA), and through the Territory Plan, administered through the ACT Government. The National Capital Plan provides a general policy framework for land use and planning in the Territory and, more specifically, guides the planning, design and development of areas of the Territory that have been identified as having national capital importance (Designated Areas). Any significant departure from the metropolitan structure for the Territory contained in the National Capital Plan requires the Australian Government's agreement to amend the National Capital Plan. Any such amendment would include consideration of matters of national significance. Included in these objectives is 'the development of a city which both respects environmental values and reflects concerns with the sustainability of Australia's urban areas'. The WSUD code addresses this and other objectives of the National Capital Plan.

4.1.4 Australian Rainfall and Run-off

Australian Rainfall and Run-off (ARR) is a national guideline document, data and software suite that can be used to estimate design flood characteristics in Australia. Published and supported by the Commonwealth, ARR is pivotal to the safety and sustainability of Australian infrastructure, communities and the environment. It provides reliable and robust estimates of flood risk and is the basis of most flood estimation undertaken in Australia. Consistent use of ARR ensures development does not occur in high risk areas and that infrastructure is appropriately designed.

The Australian Run-off Quality is a companion document to ARR and is considered to be the current industry standard for the management of urban stormwater quality. An initiative of the Institution of Engineers and Australia's National Committee on Water Engineering, it provides an overview of current best practice in Australia. It details procedures for estimating a range of urban stormwater contaminants, design guidelines for commonly applied stormwater quantity and quality management practices, procedures for the estimation of the performance of these practices, and advice with respect to the development/consideration of integrated urban water cycle management practices.

4.1.5 Australian and New Zealand Environment Conservation Council Guidelines

The Australian and New Zealand Environment Conservation Council (ANZECC) published the revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality in 2000. These guidelines provide governments and the community—particularly regulators, industry, consultants, community groups and catchment and water managers—with a framework for conserving ambient water quality in our rivers, lakes, estuaries and marine waters. The guidelines form the central technical reference of the National Water Quality Management Strategy, which the Commonwealth and all state and territory governments have adopted for managing water quality. The ANZECC Guidelines assist in identifying environmental values and water quality objectives for a site's receiving waters.

The primary aim of the Guidelines for Managing Risks in Recreational Waters is to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters. Threats may include natural hazards such as aquatic organisms and those with an artificial aspect, such as discharges of wastewater. These guidelines were developed by the National Health and Medical Research Council and are a tool to assist in the development of legislation and standards to ensure that recreational water environments are managed as safely as possible.

4.2 ACT POLICY CONTEXT

4.2.1 Territory Plan

The Territory Plan is the key statutory planning document in the ACT, providing the policy framework for the administration of planning in the ACT. The purpose of the Territory Plan is to manage land use change and development. The WSUD Guideline provides developers, residents and ACT Government officers with support on introducing WSUD into their urban residential lot, streetscape, neighbourhood and estate. The WSUD Guideline supports the Waterways: Water Sensitive Urban Design Code (the WSUD General Code). The WSUD General Code is a General Code under the Territory Plan.

There are three types of assessment codes in the Territory Plan:

- » Precinct codes, which apply to geographical areas (e.g. the Inner North Precinct Code or Local Centres Precinct Code);
- » Development codes, which apply to specific zones or development types (e.g. Residential Zones—Development Code, Commercial Zones Development Code).
- » General codes, which may apply to defined development types and/or planning and design issues (e.g. Parking and Vehicular Access General Code or Access and Mobility General Code).

The Territory Plan contains WSUD provisions as a set of rules and criteria in the three types of assessment codes. Rules provide definitive controls for development; some rules are mandatory while others may allow criteria to be met. Proposals that follow a ‘code track’ for development approval must comply with all rules relevant to the development. With the increase in development types that can now be considered exempt from development approval, few developments are considered in the code track.

Criteria provide the qualitative controls for development. Proposals that follow the ‘merit track’ can comply with the rules or the criteria unless the rule is mandatory. If meeting the criteria instead of a rule, the proponent must demonstrate, using supporting plans and/or written documentation, how the proposed development satisfies the criteria.

4.2.2 The Territory Plan and WSUD

The Waterways: Water Sensitive Urban Design Code (WSUD General Code) contains rules and criteria for:

- » reduction in mains water use
- » stormwater detention
- » climate change adaptation
- » stormwater retention
- » stormwater quality
- » entity (government agency) endorsement.

These apply to all development zones to support the objectives of the relevant zone. The WSUD General Code contains a consolidated suite of WSUD provisions that are applicable to all developments across all zones, unless another code has explicit WSUD provisions.

Under the *Planning and Development Act 2007*, where more than one type of code applies to a development and there is inconsistency between provisions, the order of precedence is: precinct code, development code and general code.

The WSUD Guideline guides stakeholders within the Territory who need to or would like to implement WSUD in their development or urban block. The guideline helps proponents meet requirements under the Territory Plan for their development or introduce ideas that can apply to the block.



This guideline is a support tool to the WSUD General Code. For most development applications, some form of WSUD provision will most likely apply, so the relevant code must be followed.

4.2.3 The ACT Municipal Infrastructure Standards

The ACT Municipal Infrastructure Standards supersede the Design Standards for Urban Infrastructure. Managed by the TCCS, they provide a broad scope and a series of standards of municipal infrastructure development and management in the ACT.

For the purposes of this series of standards, municipal infrastructure pertains to road works (except arterial and higher order roads), stormwater and landscaping required to service residential, commercial and industrial estates for both greenfield and brownfield/urban infill developments. They are works to be owned and maintained by TCCS and to be constructed either by a developer and gifted to the ACT Government or constructed as part of the ACT Government Capital Works program.

4.2.4 The ACT Municipal Infrastructure Technical Specifications

The ACT Municipal Infrastructure Technical Specifications provides a uniform specification for use in the construction of civil engineering and landscaping works within the ACT.

While based on the earlier ACT Public Works Basic Specifications, it has been significantly expanded and updated to include new technologies and Quality Assurance requirements and to bring it into line with Australian best practice.

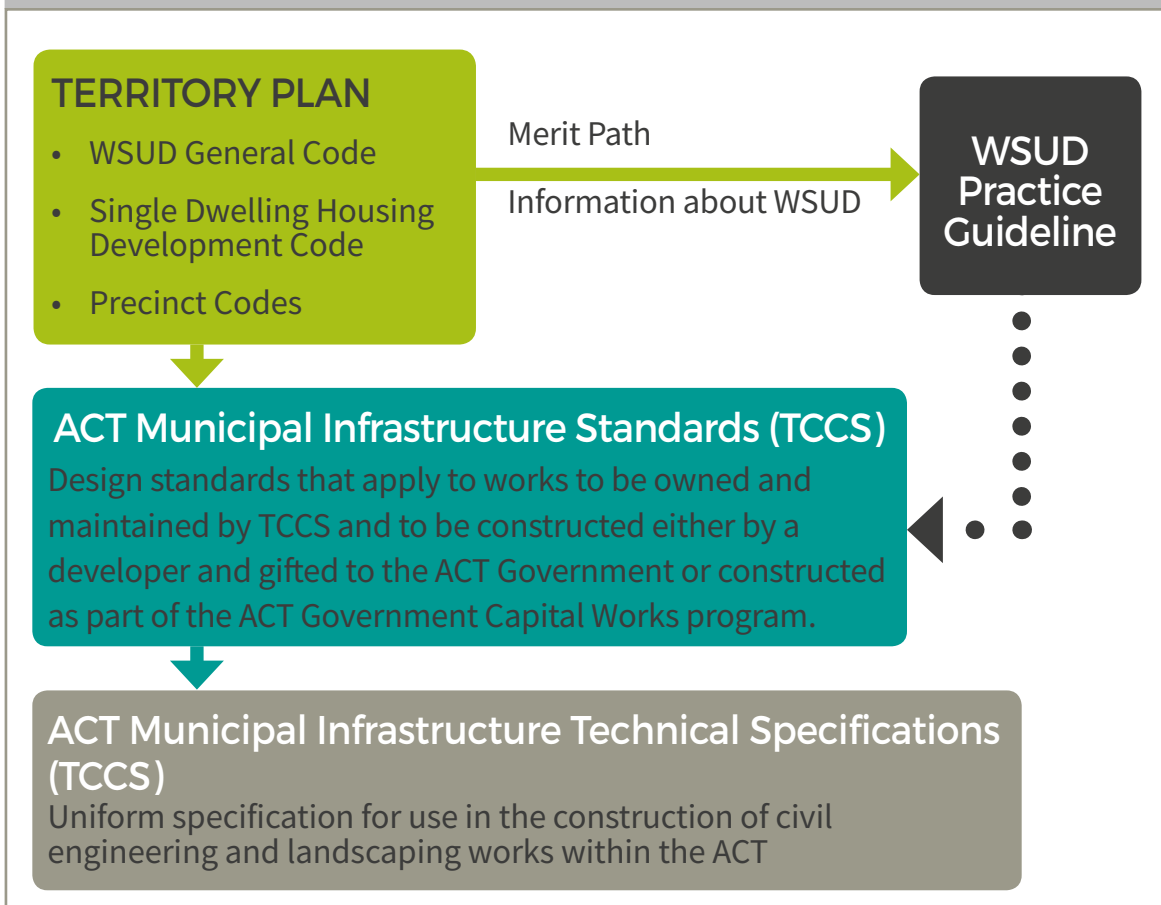
The standard specification primarily applies to urban services capital works contracts and projects involving the construction of infrastructure destined for transfer to TCCS, supervised by experienced professional engineers/landscape architects. In the interests of uniform construction standards, its appropriate use on other contracts within the ACT is encouraged, but the ACT Government accepts no liability with regard to its use by others.

4.2.5 Relationship of WSUD policy context

The diagram below illustrates the relationship between the various policy instruments and resources governing development in the ACT and the role of this WSUD Practice Guideline in informing the process.



Figure 9: Overview of the relationship between the Territory Plan and TCCS Municipal documentation



4.3 RELATED ACT PLANS AND POLICIES

By adopting WSUD practices in the ACT, the ACT Government supports and delivers related environmental policies where water plays an important role.

- » **ACT Water Strategy – Striking the Balance 2014–44 (Water Strategy)** sets a strategy for water management in the ACT over the next 30 years. The Water Strategy’s vision is: ‘A community working together, managing water wisely to support a vibrant, sustainable and thriving region’. WSUD is intrinsic to the implementation of the Water Strategy as it encourages reduced mains water use, improved stormwater quality and management of stormwater flows and promotes greywater reuse. WSUD is about working with communities to ensure the planning, design, construction and retrofitting of urbanised landscapes are more sensitive to the natural water cycle.
- » **Water Resources Act 2007 (ACT)** is the governing legislation for managing water resources in the ACT, defining access rights to surface and ground water resources, environmental flow provisions, water licensing requirements, resource management and monitoring responsibilities and setting penalties for water-related offences.
- » **ACT and Region Catchment Strategy 2016–2046 (Catchment Strategy)** aims to guide and deliver priority actions for the benefit of the region as a whole. The ACT and Region, located within the Upper Murrumbidgee Catchment, is unique in having multi-jurisdictional influences of federal, state and territory governments and local councils, making it a complex catchment to manage.

The ACT and Region Catchment Strategy has a 30-year vision, recognising that the region is the economic hub and current and future growth centre for south-east NSW. It details the key factors predicted to affect the catchment and includes 19 actions to promote a healthy catchment region. Key issues include climate change, an increasing population, and the challenges of multi-jurisdictional governance. The strategy aims to bring governments, community and industry together to produce a healthy, productive, resilient and liveable catchment region.

- » **Environment Protection Act 1997 (ACT)** provides for the protection of the environment. The Water Quality Standards detailed in the Act and the Environment Protection Regulation 2005 list the necessary water quality to support the water uses referred to in the Territory Plan. The Water use and Catchment General Code, within the Territory Plan sets the permitted uses for waters in the ACT and their catchments according to the predominant water use or environmental value. The three types of water use are:

1. conservation
2. water supply
3. drainage and open space.

Each category has a water use policy which sets specific objectives and environmental values in the water use and catchment policies of the Territory Plan.

- » **The ACT Climate Change Adaptation Strategy** facilitates the adaptation of the ACT community to the current and future impact of climate change. The synergies between the WSUD General Code and the adaptation strategy include:
 - reducing the urban heat island effect in the town centres and higher density areas of the ACT
 - mitigating the severity and impact of heat waves on the vulnerable members in our community
 - creating urban refuges in parks with cooler micro-climate conditions
 - reducing the reliance on potable water supply and increase the resilience of the water supply network in the ACT.

WSUD is influenced by, and impacts on, a range of associated ACT plans, strategies and projects including the Territory Plan mentioned above. WSUD is also integral to the following:

- » **Climate change: The ACT's climate change strategy and action plan, AP2**, includes actions that require risk management and mitigation and adaptation measures in our built environment. The ACT Climate Change Adaptation Strategy (2016) identifies our priorities for adaptation and coordinates our work so we can build resilience. The strategy looks at how the built environment and urban open spaces will be developed to respond to climate change through long-term mitigation objectives.
- » **Living (green) infrastructure strategy:**
A proposed new strategy will require more consideration for the protection of soils and provision of green infrastructure (urban parks etc.). There are clear synergies with the WSUD practices, in particular in the areas of:
 - providing multi-purpose public open space, delivering public amenity and ecosystem functions
 - passive irrigation of vegetated landscapes and urban trees, providing vegetation health benefits as well as contributing to achieving water quantity and quality objectives
 - supporting business cases for provision of higher amenity or larger public open space by the inclusion of the ecosystems services function (pollutant load reduction, reduction in peak flows) in the evaluation of benefits and costs.

Management plans and strategies focused on living infrastructure management already exist in the ACT such as those for open spaces, parks and reserves and the urban lakes and ponds.

- » **Catchment management and governance:** WSUD is a useful tool for catchment management. The government is considering options for catchment governance to improve whole-of-government and regional communication, collaboration and coordination through catchment masterplans.
- » **Catchment and stormwater management:** There are currently no strategic catchment and stormwater management plans for the ACT. The new long term ACT Water Strategy 2014–44: Striking the Balance, which replaced Think Water, Act Water, proposes the development of an ACT integrated catchment management plan. Consultation on the ACT Water Strategy and the WSUD review has highlighted the need for a stormwater plan or strategy that would:
 - develop an integrated blueprint for stormwater and wastewater for the ACT
 - transition Canberra to a water sensitive city and acknowledge the need to manage urban water in an integrated way



- address appropriate stormwater harvesting
- address flood risk in existing and future development
- support appropriate research and encourage innovation
- provide an appropriate institutional framework for implementing stormwater initiatives.

EPSDD is finalising a major study into ACT hydrology using a systems approach to provide better catchment specific information to inform better WSUD design and flood management requirements.

- » **Bushfire management:** The Strategic Bushfire Management Plan guides the joint efforts of government and the community to suppress bushfires and reduce their impacts on human life, property and the environment. The plan is reviewed every five years, with version 2 currently being reviewed. A key theme of the review, urban vegetation management, relates to WSUD. Unmanaged dense native plantings on leased land present an observed significant risk in high risk areas, particularly in Inner Asset Protection Zones.
- » **Flood management:** The ACT Government is currently updating its flood management policy including a strategic flood risk management plan that looks at describing the different types of floods (riverine, flash and stormwater flooding as well as floodplain management) and the types of flood risks associated with it. Stormwater quantity management is addressed in the WSUD General Code and can help mitigate nuisance flooding.

4.4 RENEWED FOCUS ON MAINTENANCE REQUIREMENTS AND OPERATING BUDGETS

Through the first generations of WSUD assets in the ACT it became clear that insufficient consideration was given to the operational phase of assets; in many instances the operation and maintenance of assets is inefficient, costly and solely the responsibility of the ACT Government.

Consequently, the new Guidelines place a much greater focus on solutions that consider how the WSUD asset is designed, constructed and established to minimise its ongoing operating and maintenance requirements. The Guidelines recommend that proponents:

- » transparently determine life-cycle cost analysis and cost benefit of WSUD assets
- » identify appropriate staged construction and establishment methods
- » clearly document the proposed maintenance requirements
- » document and cost the operating and maintenance regime under normal operating circumstances.



5. KEY OBJECTIVES OF WATER SENSITIVE URBAN DESIGN IN THE ACT

The specific requirements for the application of WSUD in the ACT have been articulated as a series of targets and objectives in the Waterways: WSUD General Code 2017 under broad categories:

- » Mains water reduction (potable water use)
- » Stormwater quantity (onsite retention and onsite detention)
- » Stormwater quality
- » Climate change adaptation (adaptation to potential future impacts of climate change)
- » Entity (government agency) endorsement (municipal infrastructure has effective ongoing operation and maintenance).

This section includes a general introduction to the respective specific policy intents. This information may be used to support constructive discussions between proponents, practitioners and ACT officers.

5.1 MAINS WATER USE REDUCTION

Development is required to support increasing efficiency in potable water use. As a minimum, a reduction of 40% compared to 2003 levels is required for all new developments. This reduction in potable water use evaluates the internal water consumption in households, and outdoor irrigation and other external water uses.

It is, however, important to note that voluntary—and readily achievable—further reduction in potable water consumption can be achieved by substituting potable water with either rainwater or greywater for outdoor uses. These practices are encouraged, but not required.

New developments can now also factor in the use of landscaping (such as water efficient plants) as part of this calculation. Refer to the Waterways calculator which now includes non-irrigated pervious surface or xeriscape garden area.

5.2 MANAGEMENT OF STORMWATER QUANTITY

Developments larger than 2000 m² and multi-unit developments must comply with on-site stormwater retention and detention requirements to provide waterway stability and flood management.

5.2.1 On-site retention of flows

Stormwater retention or on-site retention (OSR) refers to stormwater storage and reuse of stormwater on site. This reduces the total volume of run-off, which has multiple benefits (e.g. water quality and water security).

OSR allows a significant portion of run-off to dissipate through natural processes such as infiltration, evaporation and transpiration. OSR systems promote beneficial reuse of run-off, reduce the frequent flushing flows in urban watercourses and improve catchment water quality outcomes by protecting downstream environments from scour and erosion. Reuse can include use in households and buildings for toilet flushing or other non-potable uses, in landscape watering or infiltration to groundwater.

In the WSUD General Code OSR needs to be considered for:

- » developments greater than 2000 m²
- » developments within existing urban areas that increase impervious area by 100 m².

To comply with the rule, these developments must retain water on site; the stormwater storage capacity of 1.4 kL per 100 m² of total impervious area is provided specifically to retain the stormwater generated on site. Alternatively, the development must retain water on site with the site capture, storage and reuse of the first 15 mm of rainfall event falling on the site.

Why this figure?

The 1.4 kL per 100 m² approximately equates to the volume required to capture 15 mm of rainfall from an 80% impervious catchment. It provides a simple solution for applicants who want to avoid the calculations involved.

Other jurisdictions that regulate retention do so on a rainfall depth basis. Capturing 15 mm of rain that falls on a site focuses on reducing the total stormwater volume. It is more effective than sizing a tank based on impervious area.

To comply with the criterion, these developments must comply with one of the following:

- » have a stormwater offset agreement where an equivalent volume of stormwater is stored and used at an off-site location
- » or contribute to the construction of an off-site measure as a means of an offset.

Urban areas suffer when excess volumes of urban stormwater are generated as natural hydrological regimes are altered and pressure on urban creeks increased. However, this excess stormwater can be managed by the introduction of stormwater harvesting and reuse.

For many years, in particular during the prolonged Canberra drought from 1997 to 2009, stormwater harvesting had been considered a water security initiative to supplement our potable water resource.

The WSUD Guidelines suggest that stormwater harvesting be considered as an environmental impact mitigation strategy. Applying fit-for-purpose approaches, stormwater can readily be reused for non-potable demands.

OSR can be achieved at estate level, individual site level or a combination of these. This avoids duplication of mechanisms proposed at estate level or individual block level when development applications are lodged.

To achieve this retention requirement, flows can be stored for re-use or encouraged to infiltrate, evaporate or transpire through natural processes. Suitable uses include the following:

- » Toilet connections – calculating all toilet connection may be regarded as contributing to this reuse requirement. Based on MUSIC, the assumption that all toilets are connected will result in total stormwater volume reduction (through usage).
- » Laundry: Rainwater tanks connected to the laundry will help reduce water levels in the rainwater tank, thus making more space available to capture more water during the next storm.
- » Outdoor irrigation: Rainwater tanks can be used for lawn/garden watering. Increasing the demands on a rainwater tank by attaching more uses such as outdoor irrigation saves more mains water.

Note: If retained stormwater is intended for infiltration then consideration should be made to the fact that ACT has natural clay soils that may not be conducive to this. The duration of stormwater storage should avoid it becoming septic.

5.2.2 On-site detention

Stormwater detention or on-site detention (OSD) is defined as the short-term storage and release downstream of stormwater run-off to ensure the municipal infrastructure capacity is not exceeded. Stormwater discharge to the drainage system is at a reduced rate over a longer period of time. This reduces the peak flow rate of run-off, a common cause of erosion and flooding.

Run-off is detained in these systems for up to six hours. These systems can be combined with stormwater retention/OSR systems and within lakes and ponds.

OSD is generally required for redevelopment involving commercial, industrial or multi-unit residential premises where there is insufficient capacity in the downstream municipal stormwater system to cater for the increased run-off resulting from the development.

In the WSUD General Code on site detention needs to be considered for:

- » developments greater than 2000 m²
- » developments within existing urban areas that increase impervious area by 100 m².
- » estate development plans.

Developments greater than 2000 m²

To comply with the rule, these developments must provide stormwater detention measures designed to detain stormwater and release it over one to three days; the stormwater capacity of 1 kL per 100 m² of total impervious area is provided to specifically detain stormwater generated on site. Alternatively detained stormwater is designed to be released over a period of 6 hours after the storm event.

Why this figure?

The 1 kL per 100 m² for OSD is focused on achieving a peak flow rate mitigation goal rather than total volume reduction. This is not to be confused with the OSR requirement as they have different intentions. The 1kL figure mitigates the increase in peak flow in a frequent (1EY) storm event when going from rural to urban land use. Some QLD and NSW jurisdictions use a 24 hour release period after a storm event, Canberra's smaller urban catchments have a critical rainfall duration typically between 15 minutes to two hours. Therefore spreading the peak flow over a period of 6 hours is considered an appropriate way to reduce the risk. It also ensures that calculations do not underestimate the volume required for municipal assets to mitigate peak flow for a broad range of events.

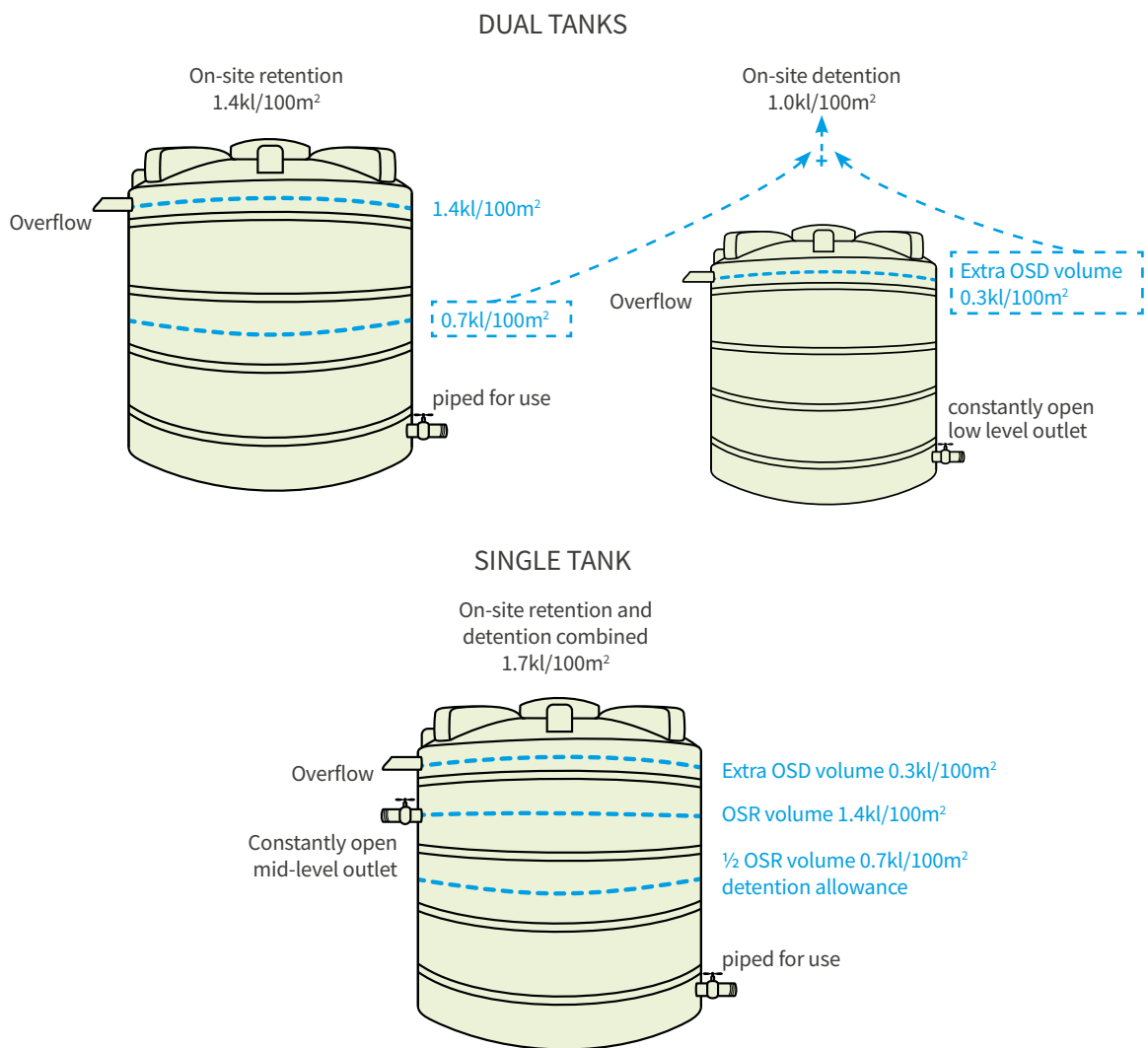
To comply with this criterion, stormwater detention measures must ensure that the peak rate of stormwater run-off from the site does not exceed the peak rate of run-off from an unmitigated (rural) site of the same area for the 1EY (Exceedances per year)¹.

¹ Exceedances per year is the new probability terminology part of the Australian Rainfall and Runoff.

Why this figure?

For on-block OSD the frequent 1EY storm event was chosen to balance the need to reduce regular nuisance flooding in our suburbs and reduce the need for new underground pipe systems while minimising the costs of development. The figure chosen mitigates the increase in peak flow in a 1EY storm event when going from rural to urban land use. Note that the 20% (previously 5 year ARI) and the 1% AEP (previously 100 year ARI) event peak flow rate must still be mitigated at an estate scale.

To achieve this detention, a 2000 m² site with 80% of impervious area would require short-term storage with a size of 15.6 kL. This equates to 1 kL per 100 m² of impervious area. A constantly open low-level outlet of approximately 10 mm diameter would allow flows to leave the tank at a constrained rate throughout (and following) the storm event. Calculating on-site detention can include 50% of the volume of rainwater tanks where stormwater is used on-site. In this case, a 28 kL retention storage would reduce required detention storage by 14 kL.



N.B. Both have the same total storage so 9 times out of 10, applicants will take the single tank approach

Note: DRAINS and XPRAFTS are examples of stormwater drainage system design and analysis programs typically used to model detention requirements. There is an unmitigated (rural) site node in these programs. Using the same area between an unmitigated (rural) site and a mitigated site provides a baseline and provides a fair comparison.

Calculations based on the rational hydrograph method would also be suitable for smaller blocks.

Estate development plans

Estate development plans require stormwater detention measures to ensure the estate does not exceed the peak rate of runoff from an unmitigated (rural) site of the same area for minor and major storms.

The major storm is described as the 1% Annual Exceedance Probability (AEP). Minor storms are as defined by Transport Canberra and City Services MIS08.

Event peak flow rate must still be mitigated at an estate scale.

OSD can be achieved at the estate development level, individual site level or a combination of the two. This avoids duplication of mechanisms proposed at estate level or individual block level when development applications are lodged.

5.2.3 OSR versus OSD

Table 3:

On-site retention	On-site detention
<p>On-site stormwater retention is defined as the storage and use of stormwater on site. This reduces the total volume of run-off, which has multiple benefits (e.g. water quality and water security).</p>	<p>Previously, OSR is defined as the short-term storage and release downstream of stormwater run-off. This reduces the peak flow rate of run-off, a common cause of erosion.</p>
<p>The retained water is used on site.</p>	<p>Previously, OSR has been interpreted as OSD and incorrectly focused on the slow release of stormwater, which is an OSD function.</p>
<p>Examples include:</p>	<p>Temporary storage and controlled release of stormwater is flood focused to ensure that the municipal stormwater system is not exceeded.</p>
<ul style="list-style-type: none"> » rainwater tanks plumbed into toilets and laundries and used for garden watering » shallow basin that retains water for infiltration and evaporation (no low level outlet). 	<p>The outflow from the storage to the existing municipal stormwater system is limited to a predetermined flow rate, which is usually the flow rate before redevelopment.</p>
	<p>Examples include:</p>
	<ul style="list-style-type: none"> » underground (typically tanks) or surface storage, such as landscaped areas » extended detention volumes in ornamental ponds or wetlands.

5.3 MANAGEMENT OF STORMWATER QUALITY

Stormwater quality requirements have been set for developments to help protect the health of downstream receiving environments. The ACT WSUD General Code (2017) provides a series of catchment-wide targets and development targets. Catchment-wide pollutant reduction targets are adjusted for percentage catchment urbanisation and percentage imperviousness. The possible ranges on pollutant removal are between:

- » 23% and 85% of the mean annual suspended solids load
- » 15% and 70% of the mean annual total phosphorus load
- » 15% and 60% of the mean annual total nitrogen load.

Refer to Appendix A General Code for adjustment calculation details.

Development-specific targets outlined in the General Code are provided below.

5.3.1 Load reduction targets

To reduce the impact of new developments such as residential and mixed-use on lake and waterway health, developments greater than 2000 m² must achieve stormwater pollutant load reductions compared with an urban catchment of the same area with no water quality management controls.

This means reducing:

- » gross pollutants by at least 90% of the mean annual load
- » suspended solids by at least 60% of the mean annual load
- » total phosphorous by at least 45% of the mean annual load
- » total nitrogen by at least 40% of the mean annual load.

These load reductions can be achieved by using current best practice stormwater treatment measures.

The baseline for stormwater quality targets has been set at an urban catchment of the same area with no water quality management controls. This is the ACT historic baseline for nutrients from changes in development. If we required sites to achieve water quality targets to match an unmitigated (rural) site, this would significantly increase the cost of development.

If the baseline was set to an unmitigated (rural) site with an allowance for additional nutrient load, the targets would need to be re-calibrated.

Canberra is commonly considered to be a largely residential community with a limited number of commercial areas and office precincts. However, the economic activity of the ACT includes some relatively large industrial and heavy industrial areas, primarily located in Mitchell, Fyshwick and Hume. Recent work carried out by the ACT Government has revealed the potentially significant environmental impact from the diffuse pollution across our industrial and commercial areas. Of particular concern is the greater abundance of heavy metals and hydrocarbons that may be washed into our waterways, lakes and ponds.

Devices that achieve the other water quality targets state that they capture hydrocarbons and heavy metals.

Compliance with this rule is consistent by this guideline and demonstrated by a report by a suitably qualified person, using the MUSIC model. If a tool other than the MUSIC model is used then a report by an independent suitably qualified person must be submitted demonstrating and confirming compliance with the code. If the parameters that are non-compliant are used then a report must also be submitted by an independent suitably qualified person stating how and why the parameters are appropriate.

The report should use Module 2 and address the different planning stages to ensure satisfaction with the WSUD Guideline. To comply with the criterion, these developments must comply with one of the following:

- » have a stormwater offset agreement where an equivalent load of pollutants is captured at an off-site location
- » or contribute to the construction of an off-site measure as a means of an offset.

Note: The methods above in 5.3.1. are also applicable to this section.

5.3.2 Load reduction target for transport infrastructure projects

Roads can generate large amounts of pollutants in urban areas. New major roads (including the duplication of existing major roads) must achieve stormwater pollutant load reductions compared to the unmitigated development scenario. This means reducing:

- » suspended solids by at least 60% of the mean annual load
- » total phosphorous by at least 45% of the mean annual load
- » total nitrogen by at least 40% of the mean annual load.

Note the methods above in 5.3.1. are also applicable to this section.

5.4 CONTRIBUTING TO ADAPTING CANBERRA'S COMMUNITY TO FUTURE CLIMATE

5.4.1 Nuisance flooding and increasing rainfall intensity

Climate change projections for the ACT predict an increase in the frequency of intense storm events. This means the capacity of stormwater drainage infrastructure may be exceeded more frequently in the future. This results in increased ponding and overland flow in property, termed 'nuisance flooding'. Nuisance flooding differs from riverine flooding in that it is associated with localised cells of high rainfall intensity. Nuisance flooding represents a significant impact for properties and people in the ACT.

As overland flows always follow natural drainage paths, the provision aims to prevent natural flow paths being obstructed with buildings, fences, roads etc.

Developments may be required to carry out hydrological and hydraulic assessment.

5.4.2 Supporting the creation of green/living infrastructure in the ACT

The ACT Government promotes living (green) infrastructure and is developing a strategy to guide the promotion and inclusion of green infrastructure in the planning and design of future urban living.

WSUD practitioners should liaise with urban designers, landscape architects and environmental scientists on projects that support green infrastructure by incorporating ecosystem services including:

- » combating urban heat island effect
- » increasing the soil moisture recharge
- » contributing to sustaining healthy vegetation and resilient urban trees via passive irrigation
- » reducing the imperviousness of surfaces
- » promoting stormwater reuse for irrigation (including passive irrigation).

Development within existing urban areas such as urban renewal sites that increase the impervious area of the site by 100m² or more will need to consider living infrastructure. Note, that the WSUD General Code does not apply to single dwellings and secondary residences subject to the single dwelling housing development code. Development is required to meet a minimum of 20% target of permeable surface area through the use of green infrastructure and permeable surfaces e.g. landscaping.

Why this figure?

A target of a minimum of 20% permeable surface area is used to encourage on-site infiltration and other ecosystem functions and is achievable. This rule has been proposed in order to balance environmental and economic value. Tank storage requirements in the past have assumed a degree of site permeability. As urban infill takes place this assumption is increasingly incorrect. Tank storage alone does not mitigate all the effects of the loss of permeable surfaces and is costly for fully impervious sites. Thus this rule balances economics (e.g. tank cost, permeable material cost) with environmental considerations (e.g. urban heat island, flood mitigation).

The introduction of large areas of impervious surfaces is a central cause of detrimental impacts on urbanised catchments. However, opportunities for introducing porous pavements and permeable surfaces include:

- » carparks and parking bays
- » footpaths and other pedestrian areas
- » public open space in general
- » driveways.

Note:

The 20% target in the rule is relaxed in the criterion. That is, if a proponent cannot meet the 20% target they must ensure that they meet the other listed requirements in the WSUD Code and those listed above.

5.5 ENTITY (GOVERNMENT AGENCY) ENDORSEMENT

The new ACT WSUD Guidelines are designed to guide and support practitioners. The ACT Government has identified varying levels of quality in the design of WSUD assets over the last decade. One source of discrepancy in the level of service obtained from WSUD assets originates from the poor documentation and lack of transparency in the planning and design of the assets. The following requirements will help improve the documentation and quality of information submitted to the ACT Government.

In the interest of clarity of design, operation and function, the design and planning process of WSUD assets are required to be transparent. In particular, the ACT Government is now in the position to audit and verify the water quality improvement claims for proposed WSUD assets. In support of this, proponents will be required to:

- » complete the WSUD planning and design process checklists (see Appendix B of Module 2)
- » submit the WSUD water quality model files (e.g. MUSIC) for compliance check
- » be available to discuss any modelling, planning or design questions following the review of their proposed design with ACT Government representatives.

Responsibility, operation and maintenance

To ensure WSUD assets continue to function as designed, on-going operation and maintenance will be required. Therefore, early identification of the responsibility for this management and the tasks required is important. It is recommended all developers have an operation and maintenance plan that identifies:

- » responsible parties through the asset life, including the handover process
- » construction and establishment approach
- » on-going water quality monitoring (if required)
- » ongoing operational requirements
- » maintenance regime
- » life-cycle costing for the asset.

It is recommended the developer be responsible for the construction and establishment of the WSUD asset so that when it is handed over to the future asset owner it is fully established and operational. For vegetated WSUD assets, a two-year establishment period is recommended to ensure the planting is fully grown and resilient. This is longer than required under the Municipal Infrastructure Standards but provides greater certainty to the ultimate asset owner (TCCS) that the system has been delivered successfully and is fully operational.

The ACT WSUD Guidelines—Module 2 provides advice on the possible construction and establishment approaches, required maintenance activities and the handover process for WSUD assets.

Access to Dickson Wetland for maintenance.



6. WATER SENSITIVE URBAN DESIGN ADOPTION FRAMEWORK IN THE ACT

6.1 PLANNING AND DESIGN FRAMEWORK

6.1.1 Metropolitan land use planning

At the most strategic level, the Territory Plan includes considerations for WSUD and catchment management. Proponents are required to understand the current zoning and any proposed rezoning proposals for their development.

The ACT WSUD General Code applies varying targets for different land uses. Precinct codes will provide any regional-specific provisions. Finally, the specific requirements of the respective development codes must be reflected in any WSUD strategies and proposals.

6.1.2 Structure and concept planning

At the structure and concept planning phase of larger developments, WSUD solutions are required to establish the large-scale framework for the future design and implementation of WSUD assets. In particular:

- » stream and inundation corridors (up to and including 1% Annual Exceedance Probability (AEP) flood levels)
- » major drainage channels
- » overland flow paths for flows exceeding pipe network capacity
- » location and dimensions of regional flow attenuation basin
- » location and extent of regional urban space corridors and parks
- » optimisation of overall water management strategy (flow attenuation, water quality improvements) according to topography, hydrographic structure and regional urban planning intents
- » definition of development specific targets, outlining the respective contributions towards the larger catchment-wide objectives.

These elements need to inform and be documented in the form of precinct codes. In the absence of a precinct code, or if a precinct code is silent on water management objectives, future development applications will be evaluated against the general provisions of the WSUD General Code.

For cost-effectiveness and infrastructure efficiency, large-scale stormwater management and WSUD strategies should be captured in precinct codes.

6.1.3 Estate planning and design

In the ACT, the Suburban Land Agency's (SLA) Estate Development and Planning Guidelines offer guidance regarding the necessary planning and design considerations expected from development proponents. WSUD and stormwater drainage form part of the requirements to be documented in an EDP submission. Block specific requirements should be included on EDP planning controls, plans and developer sales documentation so this information is transferred to builders and Multi Unit/housing and development application/building application assessors.

At the estate planning level, for the continuity of WSUD treatment trains WSUD strategies need to focus on the integration of urban design and built form and the balance between public and leased land. They must refine the general (WSUD General Code) or precinct-specific (precinct code) objectives for each sub-catchment.

The SLA EDP Guidelines are currently being revised, and will contain information relating to the specific details, format and level of documentation expected for development applications in the ACT.

6.1.4 Block and section development

Development applications and building approvals are required to be submitted for new developments. The various assessment codes in the Territory Plan provide the rules and criteria that must be met in relation to WSUD.

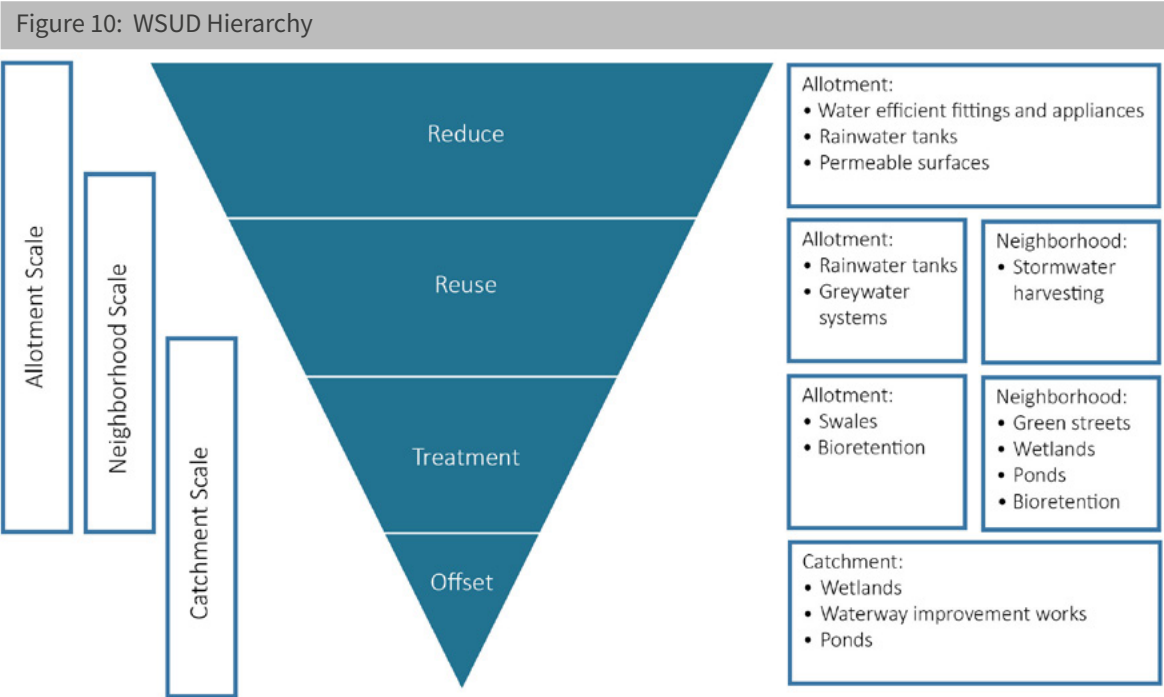
A range of WSUD measures can be implemented depending on the nature of the development and local conditions. All developments on individual blocks, regardless of whether they are residential, commercial, industrial or institutional, are required to comply with the mains water use reduction target. Any addition or alteration to a residential property that increases the floor area by greater than 50% is also required to comply with the mains water reduction target for the whole property.

The stormwater quality and quantity targets apply to all new residential estates, all residential developments with three or more residential units and any non-residential development where the total site is greater than 2000 m² for quantity targets and 5000 m² for quality targets.

6.2 WSUD SOLUTION HIERARCHY

The development of a WSUD strategy for a site should follow a hierarchy whereby water use and generation is reduced or re-used before treatment, disposal or offsetting is undertaken. This hierarchy of use is summarised in Figure 11.

This hierarchy identifies that WSUD can be delivered at a number of different scales and by many different treatment systems. It also highlights that all components of the urban water cycle—potable, wastewater and stormwater— must be considered. The following sections describe options for how this can be delivered at the individual and on-block scale and the neighbourhood scale.



6.3 INDIVIDUAL AND ON-BLOCK MEASURES

Measures can be implemented on-block to address the impact of development at its source and to add to both the aesthetic and environmental qualities of a development. On-block measures can be applied to any development, whether it is a single-residential dwelling, industrial or commercial block. Measures for block-scale implementation include structural and non-structural measures.

6.3.1 Structural measures

On-block structural WSUD measures are encouraged in all new developments to promote more responsible water management. Such measures will contribute significantly to achieving WSUD targets, particular in reducing potable water consumption.

Potable water use reduction

- » Use water efficient appliances and fixtures. The Water Efficiency Labelling Standards (WELS) allow consumers to compare the water efficiency of different products by requiring that certain products have water rating labels at the point of sale or display/advertising. The Territory requires a four star rating.
- » Install rainwater tanks to help with garden watering and internal uses (e.g. toilet, laundry cold water).
- » Use greywater for irrigation and toilet flushing in individual dwellings.

Stormwater management

- » Increase the permeable surfaces (lawns, gardens and permeable paving) to reduce run-off.
- » Disconnect downpipes and change impervious surfaces to permeable surfaces—and even allotment-scale swales or bioretention systems—with care not to direct flow to adjacent blocks.
- » Use rainwater tanks to capture and re-use roof run-off, reducing the amount of stormwater discharged from the site.

Wastewater reuse

- » Directly use untreated greywater on gardens, subject to matching soil types, plant types and water quality.
- » Install a greywater treatment system for use in toilets, laundries and gardens.

6.3.2 Non-structural measures

Some non-structural demand management measures that can be adopted at the allotment scale will help achieve WSUD outcomes by targeting behavioural change, including:

- » education, for example leaflets, factsheets, advertisements
- » incentives, for example grants to encourage adoption of rainwater tanks
- » regulation, where policies and regulations can require the adoption of WSUD and promote green infrastructure.

6.4 PRECINCT LEVEL OPTIONS

Neighbourhood or precinct scale measures can consist of a number of distributed systems throughout the development (such as street tree bioretention systems and swales) or larger end-of-pipe solutions (such as wetlands and ponds).

An appropriately sized and designed single WSUD measure at the downstream end of an estate, such as a wetland, can satisfy water quality requirements and provide recreation and amenity benefits when integrated with public open space. In large catchments containing waterways or existing water bodies, large end-of-line measures will provide no water quality benefits to those existing natural assets within the development itself. In this instance, considering a treatment train of distributed neighbourhood measures or fully integrated solutions can provide water quality benefits throughout the development and improve the local amenity.

6.4.1 Distributed neighbourhood measures

Distributed neighbourhood measures use a small systems approach to managing the urban water cycle. The distribution of WSUD measures will lessen the reliance on a single measure, improve water quality within a development and enhance both the aesthetic and environmental qualities of a development.

Distributed neighbourhood measures include:

Potable water use reduction

- » Use stormwater to replace potable water for irrigation.
- » Use wastewater treatment and reticulation in a recycled water network for demands that do not require water of a potable water standard.

Stormwater management

- » Green streets—use bioretention or swales to capture and treat stormwater flows from streets (including passively irrigated street trees).
- » Integrate bioretention, wetlands, ponds or retarding basins into small neighbourhood parks to provide stormwater quantity and quality management.
- » Harvest treated stormwater in lakes or other storages for irrigation of public open spaces.

Wastewater reuse

- » Construct a precinct scale sewage treatment and third pipe network to treat and distribute recycled water to buildings for re-use.

6.4.2 End-of-pipe measure at estate outlet

Reliance on a single measure alone is not the preferred approach and should only be used where a system of more distributed measures is not practical. As well as placing a high level of reliance on the single WSUD measure, it loses the opportunity to enhance the urban environment by including WSUD measures into the local landscape. If a single measure is required, the system must be appropriately sized. Generally this would be an appropriately sized wetland.

6.5 FULLY INTEGRATED ESTATE SOLUTIONS

The preferred implementation of WSUD stormwater management is in a fully integrated solution that includes on-block measures and neighbourhood scale measures in public spaces distributed throughout the development. This approach is beneficial as it lessens the reliance on individual measures and provides opportunity to enhance the urban environment by the inclusion of these measures into the local landscape.

It will also involve the adoption of a portfolio of diverse water sources such as rainwater, natural catchment water, groundwater, wastewater and stormwater that can be dynamically optimised depending on local climatic, ecological and socio-demographic condition.

Implementation of fully integrated measures can include both allotment scale and neighbourhood scale systems.

Table 4 compares the design considerations required for both at-source and end-of-pipe solutions, highlighting the benefits and risk associated with both.

6.6 WSUD IMPLEMENTATION CONSIDERATIONS

6.6.1 Operating and maintenance cost considerations

As mentioned previously, there is focus on managing the on-going operating and maintenance costs associated with WSUD assets. Key stages in the WSUD asset design, construction and establishment will impact the ongoing operation and maintenance of the WSUD asset, including:

- » Design—WSUD assets need to be designed to meet best practice, including ensuring there is adequate maintenance access provided.
- » Construction—the construction of a WSUD asset may need to be staged to protect it from sediment laden flows as the catchment is being built-out.
- » Establishment—it is recommended that vegetated WSUD assets have two years to establish before being handed over to ensure the vegetation is successfully established and the system is operating as designed.

Table 4: Comparison of at-source and end-of-pipe solutions identifying benefits and risks for different design considerations

Design consideration	At-source approach	On-site, end-of-pipe approach
Design levels and site grades	At-source treatment systems treat flows before they enter a pipe network so the surface level is not driven by a pipe invert level. These systems need to be able to freely drain to a downstream pipe network or waterway channel.	When stormwater flows enter a pipe before being treated, the surface level of the treatment system will be determined by the level of the pipe. If pipes are too deep, the treatment system will require very large batters (significantly increasing the overall footprint and land take) or steep banks that may require fencing. This is not ideal when trying to deliver a high amenity landscape. It is also important that these systems can freely drain to the receiving waterway or pipe network. End-of-pipe solutions are therefore better suited to undulating sites which have enough grade to allow the pipes to discharge to the surface of the end-of-pipe treatment system and freely drain to downstream receiving systems.
Scale and site suitability	Bioretention systems are ideal for at-source treatment given their relatively smaller footprint compared to other treatment options, flexibility in form/shape and lack of permanent water.	Both bioretention and wetlands are suitable for distributed end-of-pipe solutions. The site characteristics and catchment size will influence treatment device selection. If they are to be co-located with detention basins, wetlands are preferred due to their resilience to sediment loads and inundation.
Integration with landscape	At-source systems can be designed as functional streetscape garden beds or street tree pits.	Distributed systems can be designed as either natural garden or water landscapes (local parklands) or integrated into the urban area as hard edged planted landscapes (e.g. within urban plazas).

More detail on each of these stages is provided in Module 2. Module 2 also provides advice on the types of maintenance activities that are typically required for WSUD assets to help inform the development of costed maintenance regimes which can assist in the planning and budgeting of ongoing operation and maintenance works.

7. REFERENCES

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