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ACT Waterways Policy Review

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Contents

1 Introduction 13
1.1 Purpose of the Review 13
1.2 Scope of the Review 13
2 Receiving waters and stormwater management in the ACT 14
2.1 Existing condition of urban waterways 14
2.2 Existing condition of urban lakes 14
2.3 ACT waterway environmental values (Lower Molonglo and Murrumbidgee Rivers) 15
2.4 Existing pressures on water-related values in the ACT 21
2.5 Brief history of stormwater treatment in the ACT 26
3 The effectiveness of policies and strategies for lake and waterway protection in the ACT 30
3.1 Urban catchment management 33
3.2 Aquatic and riparian ecosystems 35
3.3 Water quality and flow 37
3.4 Water Sensitive Urban Design 40
3.5 Cost effectiveness of Water Sensitive Urban Design infrastructure 42
4 Evaluation of planning decision and development assessment processes that may impact water quality 45
5 The effectiveness of compliance activities and regulation in protecting waterways and riparian zones 48
5.1 Compliance with erosion and sediment controls 48
5.2 Regulatory compliance and performance of WSUD assets in the private realm (block scale) 49
5.3 Performance of WSUD assets in the public realm 50
6 Opportunities for improved governance arrangements 55
7 Consolidated recommendations 57
8 References 63
Appendix A – 2015 Review of stormwater treatment assets in the ACT 66

Figures

Figure 1. *ACT lake closure 2011-2017 (ACT Government 2017b).* 15
Figure 2. *Kambah rock pool* 18
Figure 3. *Murrumbidgee River downstream of Kambah rock pool* 18
Figure 4. *Murrumbidgee River at Uriarra Crossing* 19
Figure 5. *Molonglo River upstream of Deep Creek confluence* 20
Figure 6. *Molonglo River at the confluence of the Molonglo and Murrumbidgee Rivers* 21
Figure 7. *Summary of key water-related ecological and social values downstream of Canberra (Source: Alluvium 2020).* 22

Figure 8. *Historical erosion and gullying with deep incision downslope from Uriarra Road. Photos capturing immediately upstream of Uriarra Road, Uriarra Road and immediately downstream of Uriarra Road.* 23
Figure 9. *Giralang Pond (Source: Giralang Pond Landcare Group)* 26
Figure 10. *Lower Stranger Pond* 27
Figure 11. *Yerrabi Pond (Source: ACT Government)* 27
Figure 12. *Constructed waterway on Gungaderra Creek in Franklin (Source: Patricia Worth) and Norgrove Park wetland in Kingston* 28
Figure 13. *Holder wetlands (Source: Southern ACT Catchment Group)* 29
Figure 14. S*trategies and actions under Outcome 1 (ACT Government 2014a)* 33
Figure 15. *Priority projects identified in the Water Sensitive Urban Design Review (2014)* 41
Figure 16. *Construction sediment control issues at Coombs (Source: ACT Government)* 52
Figure 17. *Overview of asset locations* 66

Executive summary

Alluvium Consulting was engaged by the Office of the Commissioner for Sustainability and the Environment to investigate the effectiveness of key ACT Government management actions and strategies to protect Canberra's lakes and waterways and to identify any gaps or issues to be addressed, in particular to:

1. evaluate the effectiveness of strategies and policies for lake and waterway protection and the effectiveness, including cost effectiveness, of Water Sensitive Urban Design measures.
2. evaluate processes relevant to planning decisions and development assessments that may impact water quality.
3. evaluate the effectiveness of compliance and management activities and the regulation of polluting entities in protecting waterways (and riparian zones), and
4. identify opportunities for improved governance arrangements to support effective protection and management of waterways, water quality and ecological health in the ACT.

The investigation area included Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong, as well as waterways that flow through the urban area and into the Murrumbidgee River, including urban ponds and wetlands and the Molonglo River and tributaries. For the purpose of this investigation, "urban lakes" refers to the following three major constructed lakes – Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong. "Urban ponds" refers to the network of major and small ponds constructed to treat stormwater from urban areas. "Urban waterways" refers to rivers, creeks, streams or channels (including artificial channels).

There are exceptional aquatic and riparian values in the Lower Molonglo and Murrumbidgee Rivers that are nationally significant including Macquarie perch, Murray River crayfish and Platypus amongst others. Riparian zones in the ACT, particularly the Murrumbidgee and Molonglo river corridors, are noted for their high bird diversity and regional connectivity. Many waterbirds and land birds rely on aquatic and riparian habitats for breeding, feeding and resting. In contrast to the mainstems of both rivers, their minor tributaries within the ACT, many of which flow through urban areas, are generally severely degraded and are noted to contribute poor water quality when they flow. A key aspect is their engineered nature, which has significantly reduced habitat and landscape values through physical modification of the waterway and removal of vegetation.

Water quality monitoring in Canberra's lakes has revealed an accumulation of common nutrients (nitrogen and phosphorus) in them, which has contributed to triggering and maintaining numerous algal blooms with nearly all lakes experiencing extended closures in the last decade. Waterwatch data shows the overall condition of urban waterways is generally fair (based on water quality surveys, macroinvertebrate surveys and riparian condition surveys) with high turbidity measurements noted in waterways adjacent to development sites including in developing suburbs in proximity of the Lower Molonglo River.

There is significant pressure placed by the urban environment on receiving waters, including within the urban catchments and also downstream, such as the Murrumbidgee River. Urban development, and unmitigated and untreated urban stormwater in particular, impacts waterways through the following processes:

- Direct modification of existing waterways and drainage lines to facilitate development
- Changes to the hydrologic regime in waterways including the magnitude of peak flows, volumes of runoff, reduced time to peak flow and changes to baseflow
- Increased pollution to waterways including sediments, nutrients, pathogens, fuel, oil, heavy metals and microplastics
- Spread of terrestrial and aquatic weeds along waterways.

Findings:

This investigation has identified the following gaps in ACT Government management actions and strategies to protect urban lakes and waterways:

- There is currently no clear governance structure to guide strategic decision-making for protecting and improving the health of urban lakes and waterways. Current ACT Government strategies (the *ACT Water Strategy 2014-44* and the *ACT and Regional Catchment Strategy 2016-46*) also do not address integrated catchment planning and management across existing and potential future urban catchments.
- There is a need for stakeholders to recognise the multiple roles that urban lakes and ponds perform and fully understand their objectives and the range of environmental, social and economic values that they provide.
- There is no clear strategy for protecting and enhancing aquatic and riparian health of urban lakes and waterways with the *ACT Aquatic and Riparian Conservation Strategy* focused primarily on natural water bodies.
- Land development is having a direct impact on waterway aquatic and riparian health including in the Molonglo and Murrumbidgee Rivers. This is arising from a lack of compliance with erosion and sediment controls during land development and limited guidance (and lack of application of existing guidance) on design of stormwater discharges at the urban edges.
- There is a need for a more coordinated approach to monitoring environmental values, flows and water quality in urban lakes, ponds and waterways with the ACT Government appearing to be relying heavily on community-based volunteer efforts such as Waterwatch.
- Flow and water quality objectives in urban lakes, ponds and waterways are not well defined for the range of social and environmental values that they provide.

Water sensitive urban design (WSUD) – an approach to urban planning and design that aims to integrate the management of the water cycle including stormwater into the urban development process – is being undertaken in the ACT. However, this investigation found a number of deficiencies in the approach including:

- Stormwater quality targets and stormwater retention targets in the Waterways WSUD code are not tied to environmental outcomes in the receiving waters. In particular, the current stormwater quality targets in the Waterways WSUD code may not be sufficient to avoid an increase in pollutant loads from greenfield developments entering urban lakes and ponds.
- There is no catchment strategy that outlines how “development targets” and “regional targets” for stormwater treatment will be applied in practice to meet the objectives for the Murrumbidgee River as outlined in the *ACT Water Strategy* and to improve the condition in urban lakes and waterways.

This investigation found a number of weaknesses in the planning, design, delivery and operation of WSUD infrastructure including:

- The agency-focused negotiation process at the planning and design stage is not necessarily tied to stormwater management objectives and environmental outcomes.
- Consultation during development application and design review stages does not always engage with all relevant entities in the ACT Government (or teams within the relevant entities).
- Sometimes, a lack of capacity or capability hinders ACT Government staff from undertaking meaningful review at development application and design review stages.
- Limited capacity in industry means WSUD assets are sometimes poorly designed and fail to provide the level of service required once constructed. There can also be poor integration of ecological, hydrological, and geomorphological disciplines, which means stormwater, landscape and ecological outcomes may suffer.
- There can be insufficient coordination between teams planning estate WSUD infrastructure and teams planning regional WSUD infrastructure, resulting in sub-optimal outcomes for stormwater treatment.
- There is a need for existing urban lakes and ponds to be redesigned and retrofitted with appropriate structures to meet the water management zone requirements of the *Canberra Urban Lakes and Ponds: Land Management Plan* (ACT Government 2019c).
- Excessive sediment loads into, and damage to, WSUD assets at the home construction stage.

- Little attention to the establishment of a vegetated stormwater treatment system.
- There is a likelihood of deficiencies in rainwater tank plumbing connections and in the quality of products, including pumps and diverters.
- The ACT Government is under-resourced for optimal operation and maintenance of WSUD assets.

Finally, this investigation found that WSUD assets constructed under the *ACT Healthy Waterways* program were cost effective and the program itself was economically viable. In particular, constructed assets were cost-effective at managing Total Nitrogen and Total Suspended Solids when compared with the average of estimates in other jurisdictions, but less cost-effective at managing Total Phosphorus. From a cost-benefit analysis (total benefits assessed against total costs), the *ACT Healthy Waterways* program had a net present value (NPV) of approximately $50 million and a benefit-cost ratio of 1.66 based on a 30-year appraisal period.

Recommendations:

To address the pressures on urban lakes and waterways, catchment management and planning is required at an urban catchment scale. A focus on urban catchments is important because there is significant pressure placed by the urban environment on receiving waters from stormwater, and the impacts are ongoing and will not improve without a concerted and planned effort over time. There is also much social value to be gained from improving the condition of lakes and waterways in urban areas as they contribute to community wellbeing.

All recommendations arising from this investigation are consolidated in the table below, along with suggested broad timeframes for their implementation.

Recommendations	Timeframe*
Urban catchment and waterway management and governance	
Consideration should be given to: • Establishing an entity that is responsible and accountable for integrated catchment management at the urban and peri-urban scale and for making strategic decisions for the urban lakes, ponds and waterways including stormwater management in the ACT. • Developing a long-term funding strategy to support the activities of the proposed entity based on revenue collected from the ACT Water Abstraction Charge (WAC). • Aligning the activities of the proposed entity to the 10 actions under the "*ACT Water Strategy* Outcome 1 – Healthy catchments and waterbodies".	Short term
Consideration should be given to establishing a process that ensures coordination of regional WSUD infrastructure and land use planning in catchments, and that infrastructure is planned and designed in line with stormwater management objectives for the catchment. This should include consultation with the proposed integrated catchment management entity (see above).	Medium term
Agency and stakeholder coordination	
Consideration should be given to: • Developing a stakeholder consultation plan to ensure the right stakeholders are consulted at each stage of the WSUD asset life cycle, including in repeat cycles. The consultation process should begin in the strategic planning phase with early establishment of operation and maintenance requirements. • Undertaking occasional external audits to assess processes at each stage of the WSUD life cycle including development approval, asset design approval and asset acceptance processes.	Short term and ongoing
Consideration should be given to having contracts that encourage an integrated approach from developers and their consultants, supported by multi-disciplinary teams within ACT	Medium term

Recommendations	Timeframe*
government (e.g., covering urban planning, urban and landscape design, bushland and waterway management, engineering, WSUD on project teams).	
Communication of the key roles and objectives of each urban lake and pond	
Consideration should be given to: • Reviewing the *Water Use and Catchment General Code* to reflect environmental and community values of urban lakes, ponds and waterways including requirements for water quality and flows. • Developing better linkage between the *Water Use and Catchment General Code*, the Waterway WSUD code and the *Canberra Urban Lakes and Ponds: Land Management Plan*	Short-term
Consideration should be given to developing flow and water quality objectives for urban lakes, ponds and waterways. The objectives should build on previous scientific studies, the *Environmental Flow Guidelines,* and the *Canberra Urban Lakes and Ponds: Land Management Plan*. Where knowledge gaps on environmental values exist, detailed field assessment should be undertaken to improve the state of knowledge (in addition to the data collected by Waterwatch).	Short to medium term
Improving WSUD practice in the ACT	
Consideration should be given to an audit of recently completed projects to determine if the quality of WSUD asset design has improved, and to obtain feedback on the application of the municipal infrastructure design standards (released in 2019).	Short term
ACT Government to continue to build its capacity in WSUD asset delivery	Ongoing
Consideration should be given to: • Continuing or re-investing in the implementation of all 8 priority projects and the list of recommendations identified in the Water Sensitive Urban Design Review report (ACT Government 2014b) as part of current or future ACT Water Strategy implementation plans. • Increasing the rule for site permeability from a minimum of 20% to a minimum of 30% under the green/living infrastructure element in order to align with the Living Infrastructure Plan's target of 30% permeable surfaces in Canberra's urban footprint by 2045. • Increasing the mains water use reduction target from 40% to 50% of pre-2003 levels in all new developments and redevelopments. This is due to improvements in recent years in the efficiency ratings of household plumbing fixtures and appliances, the potential for inclusion of flow restrictors on outdoor plumbing fixtures, and the potential to increase roof water collection area requirements. • Defining the term "reuse" in the stormwater retention objective so that combination of indoor end uses, infiltration, evaporation and evapotranspiration measures are acceptable. • Amending the Waterways: WSUD General Code to require stormwater quality treatment in all catchments within which urban development is planned, irrespective of whether water quality targets have been met. • Amending the Waterways: WSUD General Code to require scenario modelling and mitigation measures that ensure any development results in an EPI of unity.	Short term

Recommendations	Timeframe*
Consideration should be given to the following inclusions in the next version of the WSUD Practice Guidelines and Design Standards: • Learnings from the delivery and management of stormwater treatment infrastructure as part of the *ACT Healthy Waterways* Project and industry projects (e.g., greenfield development) to provide more ACT context to the guidelines, including details on the re-design, rectification and renewal of existing assets. • Novel solutions such as passive irrigation measures that can be used meet the stormwater retention and green/living infrastructure element of the Code. • Tools that can be used to demonstrate how green/living infrastructure criteria are met including how microclimate benefits are quantified, extreme temperatures are mitigated, and air humidity and human comfort are improved. • Updates to align with recommendations from *Canberra's Living Infrastructure Plan* and the "holistic water cycle management plan" which is scheduled to be developed 2020-21 as per the Implementation Plan Two of the *ACT Water Strategy*.	Short to medium term
Consideration should be given to establishing a program to rectify Canberra urban lakes and ponds to delineate water management zones more effectively and achieve water management zone objectives as described under the *Draft Canberra Urban Lakes and Ponds Land Management Plan*. This can build on rectification projects proposed under the 2015 ACT Basin Priority Project.	Medium term
Monitoring	

Consideration should be given to:
• prioritising Action 4 of the *ACT Water Strategy* – Improve water monitoring and analysis across the ACT and region – in urban catchments including:
  o better integration of Waterwatch and AUSRIVAS activities
  o identifying priority gaps in monitoring and undertake additional monitoring to understand the impact of extant and future urban catchments
  o monitoring performance of existing WSUD, including ponds and wetlands, with the aim of improving design guidelines for future infrastructure.
• prioritising the following, adapted from Implementation Plan Two of *The ACT Water Strategy*:
  o the identification of monitoring gaps in urban catchments
  o additional water quality and flow monitoring in urban lakes, ponds and waterways
  o assessment of water treatment performance of WSUD assets such as constructed wetlands, including monitoring of the receiving waters of treatment trains
  o improved access to monitoring data, including collected as part of the Integrated Water Quality Monitoring Program.
	Short to medium term

Urban waterways riparian and aquatic strategy	
Consideration should be given to: • Developing an urban aquatic and riparian strategy as part of the urban catchment management strategy to protect and enhance the condition of aquatic and riparian	Medium term

Recommendations	Timeframe*
environments in existing urban and urbanising areas. Guidance from the non-urban *ACT Aquatic and Riparian Conservation Strategy* could be used to inform an urban aquatic and riparian strategy with a view to improving water quality from urban areas. • Developing an urban buffer Land Use Zone adjacent to the Molonglo and Murrumbidgee River corridor zones that allows sufficient space to mitigate high stormwater flows that avoids any requirement for engineered structures within the river corridor reserves themselves. • Developing a program to rehabilitate urban waterways including: o Naturalisation of concrete channels in the lower reaches o Naturalisation of concrete swale and grassy banks in the mid reaches o Rehabilitation of disturbed reaches in the upper catchment where greenfield developments are proposed.	
Regulation and compliance	
Consideration should be given to a cross-agency arrangement between EPA, EPSDD, SLA to ensure a coordinated approach on: • Awareness campaigns with estate developers and home builders to improve engagement with and understanding of construction impacts on waterways and how to reduce them • Increasing capacity for undertaking compliance inspections, e.g., by SLA officers or by engaging building certifiers • Greater enforcement of the sediment control obligations of builders, including financial penalties • Regular audits to track progress on compliance performance, with penalties for non-compliance	Medium term
Consideration should be given to: • An audit to understand levels of compliance in terms of rainwater tank plumbing connection and quality of products installed (including indoor fixtures and appliances, pumps and diverters) • Making compliance part of the building or plumbing certification process such that all measures undertaken to meet the mains water use reduction target are certified by a suitable expert with the provision of a compliance certificate. • Making it mandatory that the rainwater tanks are connected to new houses and townhouses	Medium term
Consideration should be given to: • An audit of recently completed projects (including interviews) to obtain feedback on the application and effectiveness of options to avoid damage to stormwater treatment systems from sediment during construction as provided in the *ACT Practice Guidelines for Water Sensitive Urban Design* (released in 2018). • An audit of assets currently under establishment or recently completed (including interviews) to obtain feedback on the application and effectiveness of guidance on establishment of WSUD assets as provided in the *ACT Practice Guidelines for Water Sensitive Urban Design* (released in 2018).	Medium term

Recommendations	Timeframe*
Cost effectiveness and benefit analyses	
Consideration should be given to: • Cost-effectiveness analysis for WSUD investments prior to allocation of funds to improve decision-making in selection of projects and sites and in maximising total potential benefits from program planning. Assessment of project risks should consider impact on cost-effectiveness should certain risks eventuate. • Cost-benefit analysis in conjunction with a cost-effectiveness analysis to give transparent metrics for funding allocation and enhance communication of decision-making with stakeholders. • Undertaking primary studies to better understand the range of ecosystem service benefits derived from WSUD investments such as biodiversity improvement, urban cooling and recreation. This will improve assumptions used in cost-benefit analyses. • Education initiatives for similar programs in the future to improve behaviour changes. The benefit of lasting behaviour changes is that it can reduce the need for large WSUD asset investments in the long term.	Ongoing

***** Short term: 1-2 years, Medium term: 3-5 years

Glossary of terms

Anuran	Tailless amphibians of the order Anura i.e., frogs/toads
Integrated catchment management	An approach to management of land and water resources that aims to balance environmental, economic and social values
Integrated water management	A collaborative approach to planning that brings together all elements of the water cycle including sewage management, water supply, stormwater management and water treatment, considering environmental, economic and social benefits.
Passerine	A large order of birds (the Passeriformes) which can perch, they are also known as “perching birds”, or songbirds.
Riparian	Relating to the interface between land and a waterway.
Urban lakes	Major constructed lakes including Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong.
Urban ponds	Network of major and smaller ponds generally constructed on public land to treat stormwater runoff from urban areas.
Urban waterways	A river, creek, stream or channel (including artificial channels) in which water flows continuously or intermittently.
Water Sensitive Urban Design (WSUD)	As defined in the Waterways and WSUD General Code, Water sensitive urban design (WSUD) is an approach to urban planning and design that aims to integrate the management of the water cycle including stormwater into the urban development process which considers integrated water cycle management.
WSUD assets	Infrastructure installed in the private realm (block scale) and public realm (street scale, open spaces and others) to meet the objectives of WSUD

1 Introduction

1.1 Purpose of the Review

The investigation aimed are to:

1. Understand the quality and ecological health of our aquatic ecosystems and the impacts that the urban environment and land development have on receiving waters.
2. Review existing policies and practices relating to waterway health.
3. Identify actions for Government and the community to improve water quality and catchment health.

1.2 Scope of the Review

The scope of the investigation was to understand the effectiveness of key ACT Government management actions and strategies to protect Canberra's lakes and waterways and to identify any gaps or issues to be addressed. The investigation area included Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong, as well as waterways that flow through the urban area and into the Murrumbidgee River, including urban ponds and wetlands and the Molonglo River and tributaries. It excluded waterways and wetlands that do not flow through the urban area – e.g., those in parks and reserves, water supply catchments etc. and drinking water reservoirs.

The investigation involved:

1. evaluating the effectiveness of strategies and policies for lake and waterway protection and the effectiveness, including cost effectiveness, of Water Sensitive Urban Design measures.
2. evaluating processes relevant to planning decisions and development assessments that may impact water quality.
3. evaluating the effectiveness of compliance and management activities and the regulation of polluting entities in protecting waterways (and riparian zones), and
4. identifying opportunities for improved governance arrangements to support effective protection and management of waterways, water quality and ecological health in the ACT.

Recommendations, and suggested timeframes for them, have been provided.

2 Receiving waters and stormwater management in the ACT

Major constructed lakes and ponds in the ACT include Lake Burley Griffin, Lake Ginninderra, Lake Tuggeranong, Gungahlin Pond and Yerrabi Pond. There are also over eighty smaller ponds on public land in the ACT that assist to improve urban stormwater quality to protect the Molonglo and Murrumbidgee rivers. A key aspect of urban waterways in the ACT is the engineered nature of the system which has significantly reduced the habitat and landscape values through physical modification of the waterway and removal of vegetation. In the ACT, the physical form of urban waterways tends to transition from highly modified concrete channels in highly urbanised areas, to concrete swales with grassy banks in mid-reaches, to more "natural" but disturbed sections in upper reaches.

For the purpose of this investigation, "urban lakes" refers to the following three major constructed lakes – Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong. "Urban ponds" refers to the network of major and small ponds constructed to treat stormwater from urban areas. "Urban waterways" refers to a river, creek, stream or channel (including artificial channels) that passes through urban areas and in which water flows continuously or intermittently.

2.1 Existing condition of urban waterways

The Waterwatch Catchment Health Indicator Program (CHIP) collects information on condition of waterways in terms of water quality, macroinvertebrates and riparian condition. The program covers several urban waterways in the ACT and provides useful information on the state of urban waterways. However, apart from this program, there is generally limited data being collected on existing environmental values in urban waterways, as well as the lakes and ponds.

Based on 2020 CHIP report (Upper Murrumbidgee Waterwatch 2020), the overall condition of urban waterways is generally fair; with overall water quality score (based on pH, turbidity, phosphorus, nitrate, Electrical Conductivity (EC) and dissolved oxygen measurement) generally good, macroinvertebrate score generally fair, and the riparian condition scope generally poor. Heavy rains in 2020 after the preceding dry years affected water quality in urban reaches (higher nutrient levels and lower dissolved oxygen levels) potentially due to high organic matter load into the system. The State of the Environment Report 2019 (Commissioner for Sustainability and the Environment, 2019) also reports that water quality from Waterwatch data was generally good in rural and urban areas. It is worth noting that waterways adjacent to development sites also recorded high turbidity. For instance, high turbidity measurements were recorded in Deep Creek which collects runoff from the developing suburb of Whitlam to the Lower Molonglo River. This is expected to have adverse impacts on habitat and environmental values in the Lower Molonglo River.

2.2 Existing condition of urban lakes

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). These have been responsible for triggering and maintaining numerous algal blooms in Lake Tuggeranong, Lake Burley Griffin and elsewhere.

The ACT State of the Environment Report (Commissioner for Sustainability and the Environment 2019) also reports that recreational water quality over the monitoring period was poor with nearly all lakes and rivers experiencing closures due to exceedance of enterococci guidelines, with blue-green algae requiring extended closures of Canberra's lakes (Figure 1).

Community engagement during the review of the *Waterways Water Sensitive Urban Design General Code* (ACT Government 2014b) also revealed a growing concern amongst catchment groups, scientists, practitioners and Canberrans for the decreasing quality of water in 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 poor.

Lake Tuggeranong is increasingly witnessing the result of nutrient build up, with blue-green algal blooms closing the lake 10 times during the 2003 to 2011 period (Lawrence 2012), and also in more recent years. Inputs considered to be contributing to the blue-green algae blooms include phosphorus loads, organic matter loads, and fine suspended solids loads, which sustain high turbidity levels in the lake and favour blue-green algae over other (more benign) types of algae (Lawrence 2012). High peak flows from the urbanised catchment can also contribute to algal blooms by mixing nutrient-rich bottom waters into the surface water zone during high-energy storm flows. Phosphorus and nitrogen are key pollutants for urban waterways increasing the potential for algal blooms in the receiving lakes.

According to the report on the state of the watercourses and catchments for Lake Burley Griffin (Commissioner for Sustainability and the Environment 2012), water quality in the lake reflects its catchment and the biological, chemical and physical processes that occur within the Lake. The main causes of poor water quality in the lake are:

- organic matter loading in urban stormwater with decomposition of the organic matter resulting in low concentrations of dissolved oxygen
- low dissolved oxygen concentrations and poor mixing of the water column particularly during dry periods leading to release of phosphorus from sediments. These are the primary factors driving the blooms of blue-green algae
- sources of faecal pollution from urban and rural runoff, including pet, stock and wildlife faeces, regrowth of bacteria already present in the lake, and possible leakages from aging sewer pipes
- Nutrient loads from treated sewage discharges from the Queanbeyan City Council Sewage Treatment Plant
- loss of submerged and emergent water plants.

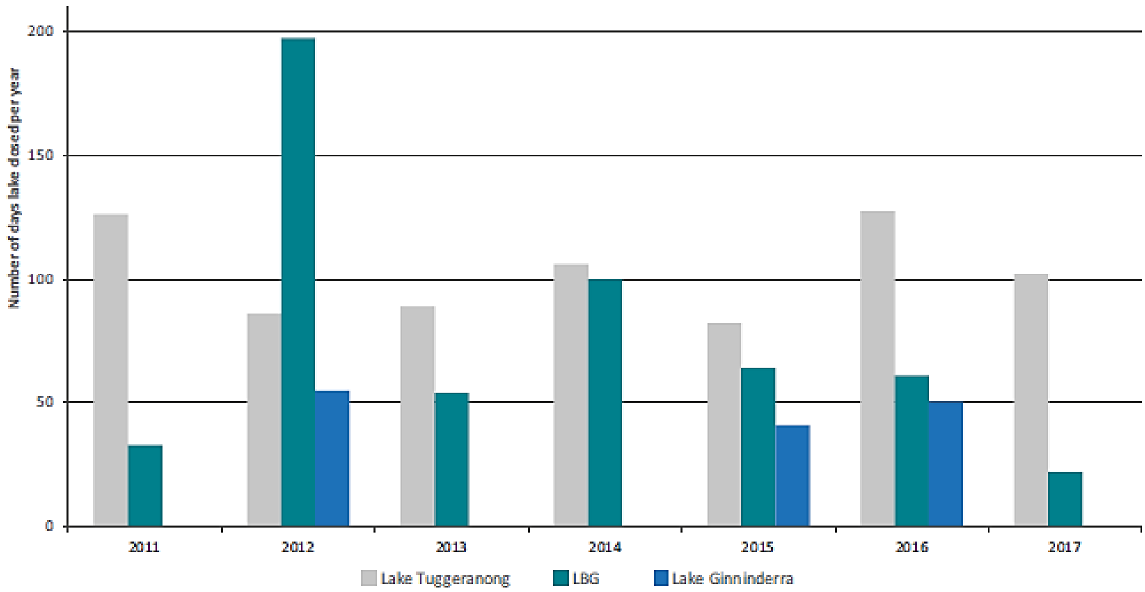

Figure 1. *ACT lake closure 2011-2017 (ACT Government 2017b).*

2.3 ACT waterway environmental values (Lower Molonglo and Murrumbidgee Rivers)

Several environmental experts interviewed in an investigation by Alluvium of future development opportunities and constraints in the Western Edge Investigation Area (WEIA) identified the Murrumbidgee and lower Molonglo Rivers within the ACT as unique, having significant riparian vegetation, and being among the last of the good reaches of these rivers in the ACT and downstream (Alluvium 2020). The Murrumbidgee River is generally in better physical condition in the ACT than for much of the rest of its length in the Upper Murrumbidgee catchment. This condition is maintained by generally better riparian vegetation in the ACT, limited stock access and steeper river gradients which prevent excessive sediment deposition (J. Overall, July 2020, pers. comm.).

Flows in the Murrumbidgee River outside the ACT are impacted by water extraction, upstream impoundments and certain rural land uses that result in substantial volumes of sand blanketing the riverbeds in low gradient areas (L. Evans, M. Beitzel and D. Starrs, July 2020, pers. comm.).

In contrast to the mainstems of both rivers, their minor tributaries within the ACT, many of which flow through urban areas, are generally severely degraded, with most having little, if any, environmental values listed, and are noted to contribute poor water quality when they flow (D. Roso, July 2020, pers. comm.).

The comparatively better riparian zones and physical condition of the Murrumbidgee and lower Molonglo Rivers within the ACT result in better quality instream habitat in these reaches. A key component of instream habitat quality is variety, including large amounts of coarse woody debris (e.g., large branches and trunks), deep holes and a range of substrates such as rocks, cobbles and boulders, rather than a relatively ubiquitous cover of sand. Better and more varied habitat supports a diverse and high-quality instream fauna (L. Evans and M. Beitzel, July 2020, pers. comm.). These include:

- Macquarie perch (*Macquaria australasica*), which is nationally endangered and found in the Murrumbidgee River from the southern extent of the ACT, downstream to Casuarina Sands near the confluence with the Cotter River (ACT Government 2018). This reach is historical habitat for the Macquarie perch (M. Beitzel, July 2020, pers. comm.), with the species noted for usually inhabiting stream reaches with abundant aquatic vegetation and typically being found near pools at least 1.5 metres deep (ACT Government 2018).

- Murray River crayfish (*Euastacus armatus*), listed as vulnerable in the ACT and NSW, is found in the same reach of the Murrumbidgee River as the Macquarie perch (ACT Government 2018), where there is thought to be a good population of them (M. Beitzel, July 2020, pers. comm.). The crayfish typically inhabits the holes between boulders and cobble and use large woody debris for cover and prefers flowing sections.

- Trout cod (*Maccullochella macquariensis*), nationally endangered. Trout cod has been identified in the Murrumbidgee River, in or close to the ACT. Following conservation stockings in 1990 and 2000's there have been reports and collections of F1 hybrids, indicating that pure bread Trout cod are present. The viability of the current population in the reach is uncertain. However, there is potential for a viable population to establish down to Casuarina Sands through stocking (M. Beitzel, July 2020, pers. comm.) and this is supported by the occurrence of a breeding event in 2005 (D. Roso, July 2020, pers. comm.). The species prefers rivers with large woody debris and pools around 2.4 metres or deeper and are known to inhabit higher flow areas than Murray Cod (ACT Government 2018).

- Silver perch (*Bidyanus bidyanus*) is critically endangered nationally. It has not been found in the Murrumbidgee River for many years (approximately 2 decades). There is a possibility of it re-establishing although this is unlikely without recovery of the population in Lake Burrinjuck (M. Beitzel, July 2020, pers. comm.).

- Murray cod (*Maccullochella peelii*) is listed as vulnerable nationally (ACT Government 2018). It is not listed as threatened in the ACT or NSW, although is listed as special protection status (SPS) under the *Nature Conservation Act 2014*. Fishing for Murray cod in the ACT is regulated under the *Fisheries Act (2000)* and managed under a *Nature Conservation Act 2014* species management plan. Murray cod is present in the Molonglo River within the ACT, primarily due to stocking in Lake Burley Griffin and subsequent movement downstream. In the Murrumbidgee, however, the Murray cod population is listed as a natural (i.e., not stocked) nationally important population (M. Beitzel, July 2020, pers. comm.).

- Water rats (Rakali) and turtles in both rivers, and platypus in the Murrumbidgee River and Molonglo. (L. Evans, July 2020, pers. comm.).

Platypus are regularly recorded from the Cotter, Murrumbidgee and Molonglo rivers, and annual Platypus Month surveys have led to the discovery of a previously unreported population (Connolly et al. 2016). Past hunting and drainage of wetlands has reduced Eastern Water Rat numbers in the ACT, though they appear to have adapted to drainage swamps and urban lakes and continue to be reported on the major ACT rivers (Ferronato, 2015). The Eastern long-necked Turtle is common and widespread throughout the ACT across urban, agricultural and natural sites (Ferronato 2015).

Riparian zones in the ACT, particularly the Murrumbidgee and Molonglo river corridors, are noted for their high bird diversity and regional connectivity (Taylor and Canberra Ornithologists Group (COG) 1992). Over 200 bird species have been recorded in the ACT and at least three-quarters of these have been recorded in the riparian zone. Few of the bird species occurring in the riparian zone are restricted to this habitat, although there are exceptions (such as wrens, thornbills, some honeyeaters and other small, non-migratory passerines).

Many waterbirds and land birds rely on aquatic and riparian habitats for breeding, feeding and resting. Additionally, the Molonglo Valley provides critical hunting and breeding habitat for birds of prey due to the mosaic of habitats in the area (rural lands, woodlands, grasslands and river corridor). At least 10 raptor species are known to nest in the riparian zone, including the Wedge-tailed Eagle (*Aquila audax*), White-bellied Sea-eagle (*Haliaeetus leucogaster*) and Peregrine Falcon (*Falco peregrines*) (ACT Government 2018).

The riparian zones in the ACT provide habitat for many species of reptiles, most of which are also found in other habitats. Snakes typically associated with riparian zones are the Red-bellied Black Snake (*Pseudechis porphyriacus*), Highland Copperhead (*Austrelaps ramsayi*) and Eastern Tiger Snake (*Notechis scutatus*). The Eastern Brown Snake (*Pseudonaja textilis*) is common throughout the ACT. At least 41 lizard species have been recorded in the ACT region and many of these are present in riparian zones with suitable substrate. The Gippsland Water Dragon (*Physignathus lesueurii howittii*) and Heatwole's Water Skink (*Eulamprus heatwolei*) are riparian species typically associated with watercourses. Stony hillsides within riparian zones of the Murrumbidgee and Molonglo rivers contain key habitat for the threatened Pink-tailed Worm-lizard (*Aprasia parapulchella*) (ACT Government 2018).

2.3.1 Murrumbidgee River Corridor (Kambah Pools to Uriarra Crossing)

The importance of the Murrumbidgee River as habitat and potential habitat for Macquarie perch, Murray River crayfish, Trout cod, Silver perch, Murray cod and Rakali has been noted above. This reflects the generally higher quality habitat in this reach compared to the Molonglo River Corridor. The Murrumbidgee River Corridor is also free of barriers and road crossings. This is further enhanced in reaches upstream of the corridor with engineered log jams constructed to provide instream habitat and deeper channels and accompanied by fencing to restrict stock access to the river (ACT Government 2018). Within the corridor reaches, the stream bed is rocky with pools, rapids, rock bars islands and sandy margins (ACT Government 2018), providing an important heterogeneity of habitat.

The frog fauna assemblage along the Murrumbidgee is highly diverse within the ACT, and includes Stony River frog (*Litoria lesueuri*), broad palmed rocket frog (*Litoria latopalmata*) and green spotted tree frog (*Litoria peroni*) (D. Starrs, pers. comm. 2020). The ACT Murrumbidgee reach is very important for Anurans refugia, demonstrating a much lower extinction incidence than many other areas in the South East region (D.Roso, pers. Comm. 2020).

North of Point Hut Crossing, River She-oak riparian forest occurs along the Murrumbidgee River (NCDC 1984, Johnston et al. 2009, Peden et al. 2011). The community is characterised by a tall tree canopy of *Casuarina cunninghamiana* (River She-oak). It characteristically forms pure canopy stands in narrow belts along the watercourses. The shrub layer tends to be sparse and the substrate is often dominated by bare soil and rock. The ground may have a thick layer of *Casuarina cunninghamiana* branchlet and leaf litter which contributes to a shady, moist ground environment. The community and associated mistletoe species are important faunal habitat. The community was severely burnt in bushfires in 2003 and most of the tree canopy was consumed. While many of the mature trees resprouted, those beyond the observed upper limit of overbank flows have died. As a result, there is a considerable reduction in area of the community with mature canopy, despite having avoided historical felling or clearing (ACT Government 2018).

The riparian vegetation occurs on narrow complex floodplains with variable rock outcrops and sandy soils. Several rocky islands and cascades occur within the river channel on which low shrubland and woodlands and riparian fringing species are established (Johnston et al. 2009). Low lying bedrock floodplains occur at the mouths of Bulgar Creek and Cotter River. Historically, the riverbanks and floodplains were all dominated by She-oak Tableland Riparian Woodland. While this is still the case, many trees away from the riverbank have died since the 2003 fire. The understorey is dominated by exotic species, in particular African lovegrass and blackberry, along with a suite of common riparian weeds (Johnston et al, 2009). This reach contains the most widespread and aggressive blackberry infestation along the Murrumbidgee River in the ACT. Extensive parts of the floodplain contain impenetrable thickets that also extend up many of the moister gullies (Johnston et al. 2009).

Figure 2. *Kambah rock pool*

Away from the steep sided face of the Bullen Range, where the river meanders and on the opposite side of the river, there are patches of Yellow Box – Blakely's Red Gum Tableland Woodland that are in particularly poor condition (Johnston et al, 2009). Remnant canopy trees are sparse or even non-existent and what remains is very open woodland or secondary native grassland in places. Of note are the kurrajongs that have survived the 2003 fire. Large swathes of burgan occur adjacent to Huntly rural lease with the occasional remnant she-oak up to fifty vertical metres above the riparian zone. These factors indicate potential shallow water tables in this reach (Johnston et al. 2009). Thickets of wattles (silver wattle on the floodplain and red stem wattle on the dry slopes), along with sweet bursaria (*Bursaria spinosa*), Cassinia species and occasionally Pomaderris spp. are thriving in the post-fire disturbance environment (Johnston et al. 2009).

Figure 3. *Murrumbidgee River downstream of Kambah rock pool*

The Murrumbidgee River riparian zone in the reach from Red Rocks Gorge to Kambah pool is noted to be one the best along the Murrumbidgee River in the ACT and commonly contains moderate to high condition riparian areas and riverine valley slopes. Vegetation communities within the reach include River Bottlebrush – Burgan Tableland, Riparian Shrubland and She-oak Tableland Riparian Woodland (Johnston et al. 2009).

The Red Rocks to Point Hut stretch of the Murrumbidgee may have acted as a refuge over geological time and is of biogeographical importance. It supports disjunct populations of an undescribed millipede Solaenodolichopus sp. which is only known in the ACT from the Pine Island area and its next nearest probable location is in northern NSW. Similarly, a species of Golden

Sun Moth *Synemon collecta*, is also only known from this section of the Murrumbidgee in the ACT with most locations in northern NSW and coastal Queensland. Blady Grass (*Imperata cylindrica*), Swamp Millet (*Isachne globose*) and Stiff Woodruff (*Asperula ambleia*) are all species rare in the ACT with disjunct distributions on this part of the river, and which are all more common further north.

Downstream of the Cotter River confluence, the reach contains long uniform stretches of complex floodplain riparian geomorphology and associated vegetation mosaics. It contains stretches of fire affected She-oak Tableland Riparian Woodland, but also has some of the longest reaches of unburned she-oaks with intact canopy, particularly north of the ACT, beyond the junction of the Molonglo River (Johnston et al, 2009). The complex floodplain at Camp Sturt downstream of Uriarra Crossing is one of the broadest floodplains in the ACT section of the Murrumbidgee River and contains relatively intact she-oak canopy, although the ground strata is highly disturbed.

The *Callistemon sieberi–Kunzea ericoides* rocky riparian tall shrubland is also well developed along the Murrumbidgee River on riverbanks and where rocky outcrops occur north of Casuarina Sands (ACT Government 2018). Overall, where this bedrock platform community occurs the riparian zone is in good condition, with a high diversity of native species and few introduced species relative to other riparian communities. The community occupies predominantly rocky substrates, hence alien species groundcover has difficulty establishing (ACT Government 2018).

Figure 4. *Murrumbidgee River at Uriarra Crossing*

Downstream of the confluence of the Murrumbidgee and Molonglo Rivers the Murrumbidgee Corridor extends through the Woodstock Nature Reserve, which contains a wetland complex that appears to be rare in the ACT, with a significant frog community and would be highly impacted by sediment loads (D. Starrs, pers. comm. 2020). These wetlands also contain distinctive vegetation communities in the Murrumbidgee River riparian zone that provide ideal breeding and refuge sites for aquatic and semi-aquatic fauna in general (Johnston *et al*. 2009).

The riparian zone of the Murrumbidgee River provides habitat for species outside of the stream channel, including:

- Murrumbidgee Bossiaea (*Bossiaea grayi*) – listed as endangered in the ACT and is only found in the ACT. It is known to occur in five locations within the riparian zone of the Murrumbidgee River from Red Rock Gorge to the Woodstock Nature Reserve (ACT Government 2018).
- *Pomaderis palida* below Casuarina sands on the east bank and the Bullen Range (M. Beitzel pers. Comm.)
- Tuggeranong lignum (*Muehlenbeckia tuggeranong*) – also listed as endangered in the ACT and is only found in the ACT. Within the ACT it is listed in the Murrumbidgee riparian zone, restricted to flood terraces, near Tuggeranong (ACT Government 2018).

2.3.2 Molonglo River Corridor (below Coppins crossing to the Murrumbidgee River confluence)

The riparian vegetation of the Lower Molonglo and rocky riverbanks and islands are important habitat of several rare or threatened plants in the ACT, including *Adiantum hispidulum, Bertya rosmarinifolia, Blechnum cartilagineum, Bossia grayi, Crowea exalata, Diuris dendroboides, Gonocarpus elatus, Muellerina bidwilli, Pleurosorus subglandulosus, Pomaderris pallida* and *Swainsona monticola.* Mistletoe growing on River Sheoak is an important food plant for the caterpillars of the Satin Azure (*Ogyris amaryllis*), which is an uncommon butterfly species in the ACT.

The reach also includes important breeding habitat for a range of raptors (ACT Government 2019). From Coppins Crossing the river runs through undulating hilly terrain until it enters the narrow-sided gorge below the aqueduct that cuts Belconnen Creek. There is a short reach from the end of the gorge past the lower Molonglo Water Quality Control Centre (sewage treatment plant) to the confluence with the Murrumbidgee River. This section of the river was surveyed in detail by Barrer (1992) whose report provides a valuable benchmark against which to compare the current state of the riparian and hillslope vegetation.

Some unusual water bugs are found in this reach from time to time. In 2019, moth larvae (Leptoceridae) and net-spinning caddisfly larvae (Hydropsychidae) were amongst the water bugs detected. The net spinners are common in flowing water and spin their nets from silk, like their close relative the moth (Upper Murrumbidgee Waterwatch 2019).

The description of the reach provided below is taken from the survey of vegetation and habitat in key riparian zones of tributaries of the Murrumbidgee River in the ACT: Naas, Gudgenby, Paddys, Cotter and Molonglo Rivers (Peden et al 2011).

At Coppins Crossing, She-oak Tableland Riparian Woodland is still present but in poor condition following the 2003 bushfire. Prior to the fire this community formed a dense cover in places. The riparian zone is dominated by woody weeds, including willows, blackberries and an assortment of exotic tree species. The margins of the river have patches of Tableland Aquatic and Fringing Vegetation Complex in good condition, containing *P. lapathifolia*, *J. usitatus* and *C. eragrostris*. As the river spreads out among the boulders in the flat-bottomed but quite narrow valley floor, the terraces and river-line have *C. cunninghamiana* with *A. mearnsii* and occasional patches of *S. nigra*, *S. fragilis, P. nigra* and *Acer negundo*. The instream vegetation includes extensive patches of *M. verrucosum* and emergent *P. australis*, *P. lapathifolia*, *J. usitatus* and *C. eragrostris*.

Close to the Deep Creek confluence, the river contains sand bars and the riparian vegetation is 3 to 15m wide. This area contains mature, well established *C. cunninghamiana* on the flood plain near the mouth of Deep Creek and in the tributary gullies. The floodplain also includes some *Typha* beds. There has been some blackberry control work in this area with variable success. There are also a few box elder (*A. negundo*), which is an invasive woody weed of increasing concern along both the Molonglo and Murrumbidgee Rivers. Deep Creek, running under the aqueduct, is a base-flow creek with *C. helmsii*, *N. officinale*, *J. articulates* and similar plants in the riparian zone. The stream channel is braided in parts of the flood plain and wetlands have formed in some subsidiary channels.

Figure 5. *Molonglo River upstream of Deep Creek confluence*

Just upstream of the gorge there is a stand of She-oak Tableland Riparian Woodland in excellent condition with plenty of mature and regenerating plants. In the upper gorge where the stream channel is a 40–50 m wide bedrock floodplain, the river may cease to flow in drought periods and between releases from Scrivener Dam. Occasional sandbars containing *M. verrucosum* cross the floodplain marking the ends of pools in dry periods. The flood terrace is weedy and includes *H. incana, E. curvula* (African lovegrass) and *Nassella trichotoma* (serrated tussock). An occasional *C. cunninghamiana* occurs in the back floodrunner above which is a bare hillslope. Throughout this area the *C. cunninghamiana* grows into the gullies. Occasional willows and box elder *A. negundo* occur in the gorge.

Further downstream the river forms a series of large pools. The fringing emergent vegetation includes some *S. validus* and *P. lapathifolia*. The Tableland Riparian Shrubland of *A. mearnsii* and *B. spinosa,* as well as willows and other weeds, alternates with the She-oak Tableland Riparian Woodland.

Approaching the Murrumbidgee River, the Molonglo opens out into a floodplain with more gentle sloping sides, a short distance above the lower Molonglo Water Quality Control Centre. The river flows across a broad delta to enter the Murrumbidgee opposite Woodstock Reserve and below the treatment plant. The riparian vegetation community is She-oak Tableland Riparian Woodland with associated understorey species. Occasional patches of willows, box elder (*A. negundo*) and some poplars can still be found.

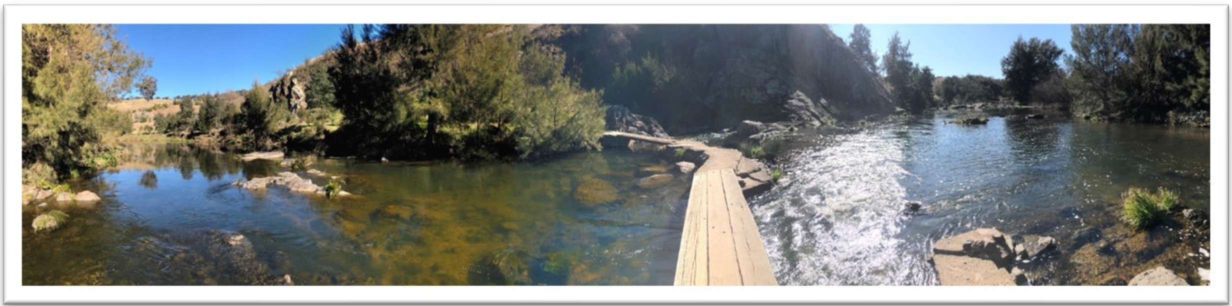

Figure 6. *Molonglo River at the confluence of the Molonglo and Murrumbidgee Rivers*

In the deeper soils of the delta region, the floor of the valley supports an extensive She-oak Tableland Woodland with many herbaceous weeds. Around the YMCA there are some plantings of poplars. On the left hillside the Black Cypress Pine Tableland Woodland is gradually replaced by open grassland with scattered exotic trees. On the right there is a remnant of Yellow Box – Blakely's Red Gum Tableland Grassy Woodland, represented by a few *E. blakelyi*.

A summary of key aquatic and riparian ecological values and water-related social values downstream of Canberra is shown in Figure 7.

2.4 Existing pressures on water-related values in the ACT

Existing pressures on the risks to water quality and aquatic ecosystems in the ACT include the poor condition of rural lands in the catchment, historical sedimentation, altered flow regimes, inputs of poor-quality waters from urban stormwater and wastewater, alien species, and recreation. These are discussed briefly below. It is worth noting that local environmental experts believe a lack of knowledge and understanding of species and ecosystems, particularly in relation to fish populations and off-stream wetlands in the riparian zone of the Murrumbidgee River and the location and management requirements of rare species in the riparian zone (e.g., *Murrumbidgee Bossiaea* and *Tuggeranong lignum*) is an overriding threat to the health of riverine systems in the ACT (L. Evans, July 2020, pers. comm.).

2.4.1 Condition of rural lands

Rural lands in the ACT have been noted to support weeds and invasive species, have very poor riparian vegetation along tributaries, allow stock access to tributaries and have severe bank erosion of tributaries. These impacts have contributed sediment delivery to the mainstem of the Molonglo and Murrumbidgee Rivers and to poor water quality, including elevated nutrient concentrations and high turbidity. This has been exacerbated by vegetation clearing contributing to increased runoff with 'flashy' flow peaks between periods of lower base flows. Destruction of riparian vegetation in the tributaries has also led to a loss of coarse woody debris habitat in the system.

Despite this, the Murrumbidgee River within the ACT is generally in better condition compared to reaches upstream and downstream, attributed to the Murrumbidgee Corridor Reserve (L. Evans, July 2020, pers. comm.), and the protection provided on the other (western) bank of the river by the Bullen Range Nature Reserve, extending from the Cotter River, upstream to beyond Kambah (D. Rosso, July 2020, pers. comm.).

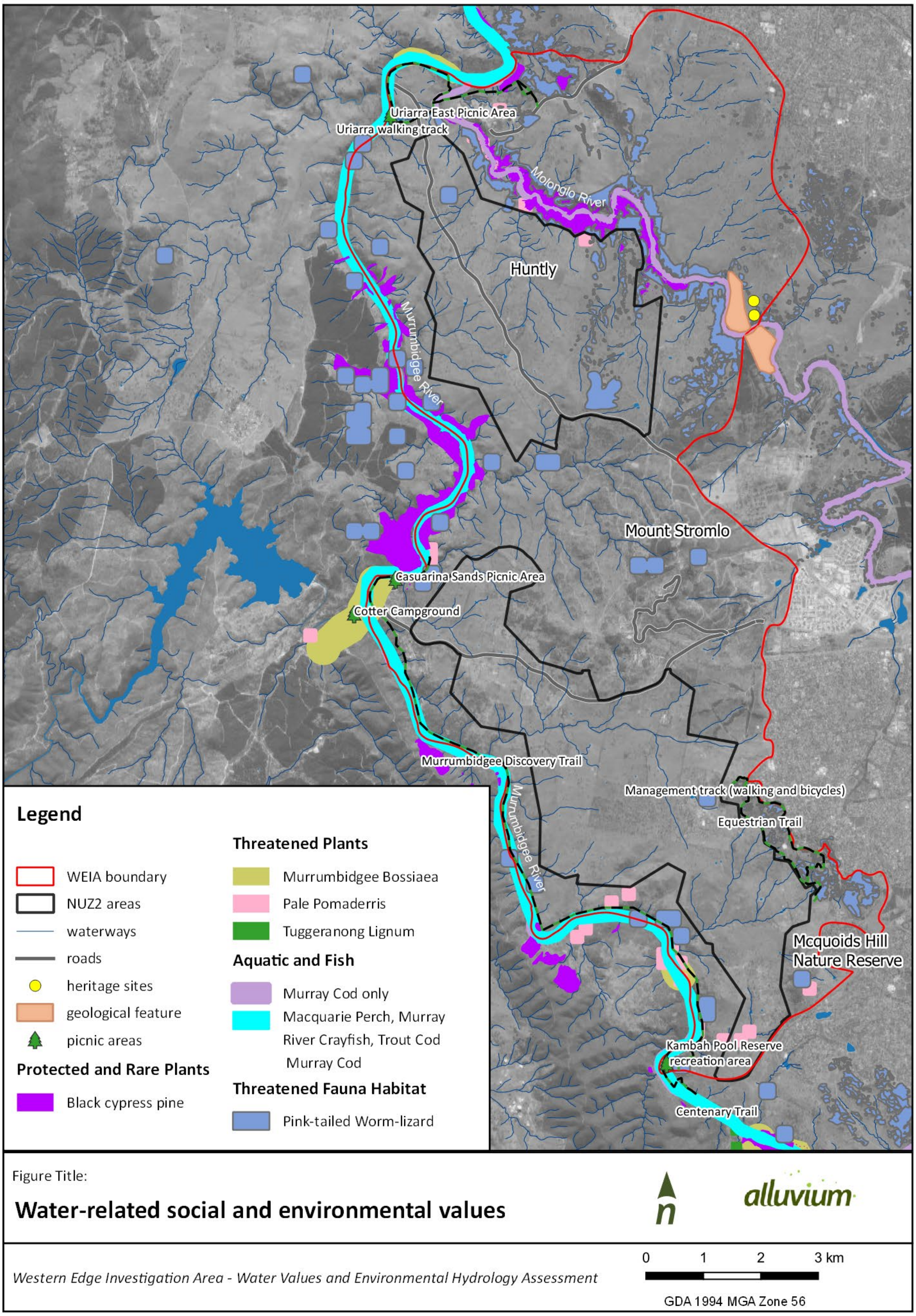

Figure 7. *Summary of key water-related ecological and social values downstream of Canberra (Source: Alluvium 2020).*

2.4.2 Historical sedimentation

Deposited sediments can take decades to be transported from a reach and can have a drastic effect on instream biota, through the smothering of structural interstitial and soft sediment habitat for macrophytes and bed fauna, as well as infilling of vital deep pools in the channel and creating shallow sand slugs which are a barrier to connectivity for aquatic species during low flow. These sediments have significant impacts on native fish species (L. Evans, July 2020, pers. comm.), and combined with the substantial flow diversions for the Snowy Hydro Scheme can cause significant stress to the Murrumbidgee River within the ACT during periods of low flow (M. Lind, July 2020, pers. comm.). A high volume of sediment input from rural land use has been delivered to the Murrumbidgee Corridor and can limit breeding of significant fish species, including the Two-spined blackfish, Macquarie perch, Mountain galaxias, Murray cod and Trout cod (ACT Government 2018). Although the Murrumbidgee and Molonglo Corridors are both affected by sediments from urbanisation, a wider buffer between the Murrumbidgee River and urban areas has reduced the potential pressures (ACT Government 2018).

Figure 8. *Historical erosion and gullying with deep incision downslope from Uriarra Road. Photos capturing immediately upstream of Uriarra Road, Uriarra Road and immediately downstream of Uriarra Road.*

2.4.3 Altered flow regimes

Reduced flows in the upper Murrumbidgee River from the construction of Tantangara Dam and climate change impacts have led to lower and shorter floods within the Murrumbidgee River (including in the ACT), resulting in reduced overbank flows and subsequent reduced resilience of riparian vegetation following events such as bushfires (Johnston et al. 2009). This threatens the riparian habitat for species and communities, as well as the potential for inputs of coarse woody debris to the channel from riparian trees (L. Evans, July 2020, pers. comm.). A lack of sufficient flow to maintain an obligate riparian species (*Casuarina cunninghamiana*) community has been observed in the Murrumbidgee River where the riparian community is being replaced by Apple Box (*Eucalyptus bridgesiana*), a species that is not an obligate riparian species and not tolerant to flooding (ACT Government 2018). The lack of flows also results in insufficient flushing of sediments in the system (W. O'Reilly July 2020, pers. comm.). Inadequate and inappropriate flow regimes resulting from the construction and management of Scrivener Dam are also a threat to native fish in the lower Molonglo River (Cheetham et al. undated), most of which are stocked fish that have been released from Lake Burley Griffin (M. Beitzel, July 2020, pers. comm.). Thermal pollution (cold water) from Scrivener Dam has also been identified as a threat to native fish in the lower Molonglo River (Cheetham et al. undated).

2.4.4 Alien species

Weeds and feral animals (especially pigs and horses) impact riparian vegetation along the mainstem of the Molonglo and Murrumbidgee Rivers, while feral fish such as European carp, Redfin perch, Oriental weatherloach, trout and Eastern gambusia impact native fish species through predation, competition and introduction of disease (ACT Government 2018). The River She-oak riparian forest community is highly susceptible to invasion by a wide variety of alien plant species (Johnston et al. 2009, Armstrong et al. 2013) and Willows are found as occasional individuals within the community (NCDC 1984). Acer negundo is of increasing concern along both of the rivers.

Steady development in Canberra's north has impacted significantly over the past 30 years, with sediment from development sites and weeds the two most significant issues. The riparian zone for many creeks is dominated by exotic grasses with a mix of native and exotic mid-storey and canopy. Some notable exceptions are areas where Landcare groups have been working for many years.

2.4.5 Recreation

Threats to aquatic and riparian flora and fauna from recreation in the ACT include recreational fishing (including illegal take, leaving fishing rubbish- line, hooks, dead fish, etc), trampling of riparian vegetation, erosion from tracks, introduction of weeds and feral animals, increased fire risk, and pets in riparian areas. Visitation can also result in damage from recreational vehicles, littering and water pollution (ACT Government 2018).

2.4.6 Urban wastewater

As well as the delivery of nutrients and suspended particles from the rural lands, discharge from lower Molonglo Water Quality Control Centre adds additional nutrients, salt and potentially other pollutants (W. O'Reilly pers. comm.). Urbanisation increases sewage outfall entering the lower Molonglo River as a result of increased population. The water from the sewage outfall is of lower quality (high in salt, nitrogen, presence of micropollutants) and a larger population (more sewage) will produce larger outfall flows. This will consequently constitute a greater proportion of the flows in the Molonglo and Murrumbidgee Rivers, causing further reduction in water quality.

2.4.7 Urban stormwater

Stormwater from urban and peri-urban areas has a higher 'flashiness' and delivers a suite of urban pollutants, ranging from gardening fertilisers and biocides (ACT Government 2018) to fuel, oil, heavy metals and microplastics from roadways and carparks. While there are water sensitive urban design codes and standards in the ACT, urban tributaries have been identified as delivering particularly poor water quality to receiving waters. The impacts include:

- Changes to the hydrologic regime, particularly the rapid delivery of storm runoff leading to erosive high peak flows scouring beds and banks. In an urbanising catchment, the changes in hydrology are likely to be an increased magnitude of peak flows, volumes of runoff, reduced time to peak of hydrographs and changes to baseflow.

- Direct modification of existing waterways and drainage lines to facilitate development. The typical modification is to construct a new or significantly modified channel to:

    - Increase flood capacity (to reduce the width of the flood extent and increase developable area)
    - Provide sufficient depth to allow stormwater pipes to drain to the waterway
    - Realign a waterway for better integration with a desired urban layout
    - Increase the amenity value of the waterway

  Significant modification of an existing waterway will generally modify and degrade any geomorphic values of the existing waterway.

Concerns associated with the impact of stormwater discharge from recent urban development in Coombs, Denman and Molonglo on existing environmental values and sensitivities (including habitat for Pink-tailed worm lizards) have led to a need to identify and implement better outfall discharge management techniques. Currently there are several different discharge situations along the Molonglo River Reserve, including to already eroding channels and to bare soils that are often highly erodible. These are resulting in flow transmission issues inside the reserve that typically include erosion and sedimentation, and degradation of environmental values.

- Large quantities of urban stormwater contaminants being delivered to tributaries and the mainstems of the Molonglo and the Murrumbidgee Rivers, including sediments, nutrients and the common suite of urban pollutants, ranging from gardening fertilisers and biocides, to pathogens, fuel, oil, heavy metals and microplastics from roadways and carparks.
- Potential reduction in creek baseflows as a result the high proportion of hard, non-permeable surfaces delivering most rainfall to the drainage system rather than infiltrating and replenishing soil and ground water.
- Increased recreational use of river corridors, including of recreation ‘nodes’, leading to increased trampling of vegetation along river edges, disturbance in and around the river (e.g., moving rocks, paddling, disturbing sediment, increased gross pollutants), and impacts on fish populations through increased fishing (legal and illegal).
- Spread of terrestrial and aquatic weeds.
- Spread of invasive species such as urban foxes, feral cats and illegal release of aquarium fish (including illegal stocking of waterways and flow retention structures).

It should be noted that Murray River crayfish in particular are highly susceptible to water pollution (Geddes 1990). Some important quotes from interviews with key stakeholders with a strong understanding of water-related ecological values within the ACT from a recent Western Edge investigation (Alluvium 2020) are provided below:

> *“There is good fish passage throughout the reach – no crossings should be built in the Murrumbidgee”*
>
> *“Just protecting the riparian zone is not good enough”*
>
> *“Turbidity is often sold as a short-term impact but sedimentation impacts last for a very long time and accumulate with each new development”*
>
> *“When heavy rock engineering occurred near the lower Molonglo River for the Coombs development, the strong vibrations and the high turbidities coincided with the loss of the platypus in the reach. This needs to be considered for the platypus population in the Murrumbidgee”*
>
> *“Developing the area would be a nightmare for that part of the Murrumbidgee, yielding catastrophic turbidity and sediment loads during construction then ongoing urban impacts, especially phosphorus”*
>
> *“Past experience suggests that this (development) won’t be handled properly”*
>
> *“Slopes should not be developed”*
>
> *“There will be no free lunch with urbanisation – we need to weigh up the values that will be lost”*

2.4.8 Land development

Major impacts during construction phases are likely to be from inputs of sediment. Studies from Lake Illawarra show that sediment pollution levels from new urban developments can be 5 to 20 times greater than from developed areas and 3 to 5 times greater than from bushland (NSW Government 2004). High rates of sediment movement may have both short- and long-term consequences for aquatic ecology, including:

- Smothering of a variety of habitats, particularly impacting on the viability of the Murray River crayfish through loss of interstitial spaces (M. Lind, M. Beitzel, July 2020, pers. comm.).

- Smothering of the eggs and breeding sites of Murray cod and Trout cod Macquarie perch and harm larvae (L. Evans, July 2020, pers. comm.).
- Filling in deep holes, thereby severely reducing viability for Macquarie perch, and reducing the potential for further re-establishment of trout cod and silver perch (L. Evans, July 2020, pers. comm.).

Other potential threats to water quality during the construction include:

- Loss of catchment trees and increased 'flashiness' and volume of flows, exacerbating sediment delivery and also increasing erosion in drainage channels, tributaries and, possibly, the rivers themselves.
- Water pollution associated with sediment inputs (nutrients, turbidity).
- Water pollution associated with spills (chemicals used in construction, fuel).

2.5 Brief history of stormwater treatment in the ACT

Lake Burley Griffin was constructed as Canberra was rapidly developing in the 1960s. While it was originally conceived as a key landscape feature in Walter Burley Griffin's plans for the city, it also functions as a stormwater treatment system, receiving stormwater runoff from a large part of Canberra's urban area. This aspect of the Lake has engendered community awareness of the impacts of stormwater runoff, and leadership in urban water management has been a long-term feature of Canberra's development.

Stormwater treatment principles have evolved over the decades and stormwater treatment systems constructed over the years have reflected an evolving approach to urban water management.

2.5.1 1970s – early stormwater treatment systems

In the 1970s the focus of urban stormwater management was on drainage, and concrete channels were a common approach to deliver stormwater rapidly and efficiently from urban areas into receiving waters. These also delivered pollutants efficiently and directly into receiving waters and the impacts of this practice were becoming evident. Therefore, in the 1970s, the first gross pollutant traps were constructed in Canberra. These included the GPT on Sullivan's Creek at Barry Drive and the trash rack on Yarralumla Creek at McCulloch Street. These are both located on large channels with large upstream catchments.

Note that Giralang Pond is also thought to have been constructed in the 1970s and is therefore an early example of a stormwater treatment pond.

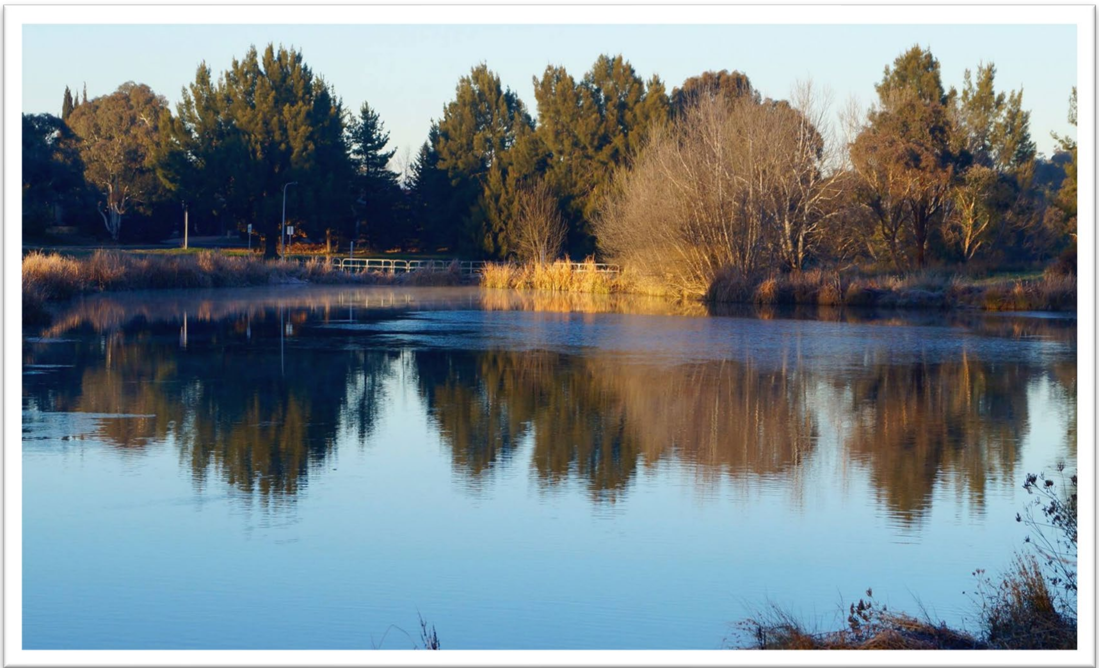

Figure 9. *Giralang Pond (Source: Giralang Pond Landcare Group)*

2.5.2 1980s and 1990s – regional ponds and lakes

Ponds are key management components with respect to securing wider flood and pollution control objectives, provision of open space, landscape amenity and recreation.

Tuggeranong was developed in the 1980s at a time when the approach to urban water management was evolving. Lake Tuggeranong and Point Hut Pond were both constructed in the 1980s, however while several of Lake Tuggeranong's tributaries (e.g., Monks Creek) were constructed as concrete channels, waterways flowing into Point Hut Pond (e.g., the Knoke Avenue waterway) have grass-lined banks with only a small concrete low flow channel.

Both Lake Tuggeranong and Point Hut Pond have few upstream treatment systems in their catchments. Isabella Pond and Isabella Lake (Upper Stranger Pond) are two exceptions immediately upstream of Lake Tuggeranong. There are gross pollutant traps at lake inlets but otherwise pre-treatment is limited.

Upper and Lower Stranger Ponds were also constructed in 1989 downstream of a smaller catchment between Lake Tuggeranong and Point Hut Pond, presumably to treat flows which could drain to neither of the larger systems.

Figure 10. *Lower Stranger Pond*

The first parts of Gungahlin were developed in the 1990s. Gungahlin Pond was built in 1989 and Yerrabi Pond in 1994 on Ginninderra Creek. These ponds are similar to Lake Tuggeranong and Point Hut Ponds, however upstream waterways include a mixture of partially concrete-lined channels (e.g., with a low-flow pipe or small low-flow channel), engineered vegetated channels and modified natural channels.

Figure 11. *Yerrabi Pond (Source: ACT Government)*

2.5.3 2000s – policy shift to WSUD

In the 2000s, WSUD became an important concept in the ACT's policies and its principles were adopted as part of the ACT's strategic planning. In 2002, the ACT Legislative Assembly passed a motion about water management, including an agreement that the water leaving the ACT via the Murrumbidgee River should be of no less quality than the water flowing into the ACT. The 2004 "*Think Water Act Water" strategy* included an objective to "facilitate the incorporation of water sensitive urban design principles into the urban, commercial and industrial development" and targets included:

- A 12 percent reduction in mains water usage per capita by 2013, and a 25 per cent reduction by 2023 (compared with 2003), achieved through water efficiency, sustainable water recycling and use of stormwater.
- An increase in the use of treated wastewater (reclaimed water) from 5% to 20% by 2013.
- The level of nutrients and sediments entering ACT waterways is no greater than from a well-managed rural landscape.
- A reduction in the intensity and volume of urban stormwater flows so that the runoff event that occurs on average once every 3 months, is no larger than it was prior to development.

Assets from this era include:

- Ian Potter Pond and Tsoulias Street swale in Gungahlin
- The constructed waterway on Gungaderra Creek in Franklin
- Norgrove Park wetland in Kingston
- David Street pond in O'Connor

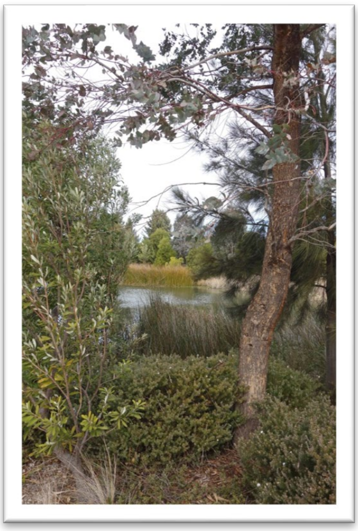

Figure 12. *Constructed waterway on Gungaderra Creek in Franklin (Source: Patricia Worth) and Norgrove Park wetland in Kingston*

2.5.4 2010s – codified WSUD

The ACT WSUD Code was published in 2009 and requires new development (above a certain threshold scale) to meet mandatory stormwater pollutant load reduction targets. The code also includes "regional" targets recommended for the ACT as a whole. The targets from the WSUD Code are shown in Table 1.

The WSUD code also encourages stormwater treatment closer to the source, with treatment systems distributed throughout an estate, as well as the inclusion of on-block stormwater treatment measures. Examples of assets constructed under the WSUD Code are those in new greenfield development including systems in the Gungahlin and Molonglo Valley districts.

Table 1: WSUD Code pollutant load reduction targets

	Development or redevelopment sites	Regional or catchment-wide
Reduction in average annual suspended solids (SS) export load	60%	85%
Reduction in average annual total phosphorus (TP) export load	45%	70%
Reduction in average annual total nitrogen (TN) export load	40%	60%

The other assets constructed in recent years include retrofit projects such as Dickson and Lyneham ponds, Emu Bank wetlands, and more than 20 wetlands, ponds and bioretention systems implemented under the *ACT Healthy Waterways* program. This period therefore includes diverse approaches to WSUD, a wide range of different types of treatment systems and a wide range of design styles.

Figure 13. *Holder wetlands (Source: Southern ACT Catchment Group)*

3 The effectiveness of policies and strategies for lake and waterway protection in the ACT

This section reviews the effectiveness of policies and strategies in place in the ACT for protection of lakes and waterways from the impacts of the urban environment. In particular, we assess how well they address the pressures of stormwater and land development on water-related values, how they compare to best practice as well as exemplary approaches in Australia, and the cost effectiveness of Water Sensitive Urban Design approach.

The ACT Government is attempting to improve the long-term health of ACT waterways through a number of policies and strategies that are currently in place and under implementation including the:

- *ACT Water Strategy 2014–2044: Striking the Balance*: A water strategy for the entire ACT with Implementation Plan Two (2019-23) now in progress (ACT Government 2014a)
- *ACT and Regional Catchment Strategy 2016-46*: A catchment strategy for ACT and Region with the first Implementation Plan cycle (2016-2021) finishing this year (ACT Government 2016a)
- *ACT Healthy Waterways*: A joint initiative of the ACT and Australian government to improve the quality of stormwater entering lakes and waterways and flowing downstream into the Murrumbidgee River system with civil works for 20 infrastructure projects completed in 2019.
- *Waterways: Water Sensitive Urban Design Code* (*Waterways WSUD Code*): ACT policy that stipulates the outcomes sought in relation to water sensitive urban design in all developments primarily through a series of targets for mains water use reduction, stormwater quality, stormwater quantity, site permeability, as well as requirement for an operation and maintenance plan for assets that are handed over to ACT Government (ACT Government 2020)
- *Water Resources Environmental Flow Guidelines 2019 (No 2)* (*Environmental Flow Guidelines*): an instrument under the Water Resources Act 2007 aiming to set out flow requirements in the ACT to maintain aquatic ecosystems (ACT Government 2019b)

The findings from the following investigations are also relevant:

- *Water Sensitive Urban Design Review* (2014) which found 16 issues with the WSUD approach in ACT and proposed a number of recommendations under 8 priority projects (ACT Government 2014b)
- *Lake Burley Griffin Action Plan: A Healthier, Better Functioning Lake by 2030* (2012) – A plan consisting of key actions to improve the health of the lake and its management (Lake Burley Griffin Task Force 2012)
- Report on the *State of Watercourses and Catchments for Lake Burley Griffin* (2012): A report released by the Commissioner for Sustainability and the Environment with the recommendations forming the basis of the *Lake Burley Griffin Action Plan* (Commissioner for Sustainability and the Environment 2012)
- *Draft Canberra Urban Lakes and Ponds Land Management Plan* (2019): A plan that documents the values and uses, management objectives, management zones and services to be provided by entities for the major lakes and ponds, as well as neighbourhood ponds (ACT Government 2019c)

This section of this ACT waterways policy review is broken into the following themes:

1. Urban catchment management
2. Aquatic and riparian ecosystems
3. Flow and water quality management
4. Water Sensitive Urban design (WSUD)
5. Cost effectiveness of WSUD infrastructure.

An overview of relevant existing policies and guidelines and their status (in place; currently being developed or reviewed; planned to be reviewed in future) is provided below.

Table 2. Overview of relevant existing policies and guidelines and their status

Policy, Guideline or Plan	Date published	Purpose	Status
The Territory Plan under the Planning and Development Act 2007	2007	The object of the territory plan is to ensure, in a manner not inconsistent with the national capital plan, the planning and development of the ACT provide the people of ACT with an attractive, safe and efficient environment in which to live, work and have their recreation.	Being reviewed
Water Use and Catchment General Code	2009	The purpose of this code is to identify waters of the Australian Capital Territory in terms of the permitted water uses and environmental values, and to identify the water quality and streamflow criteria related to the full protection of these uses and values.	In place
Lake Burley Griffin Action Plan: A Healthier, Better Functioning Lake by 2030	2012	The Action Plan proposes a coordinated program of short, medium and long term actions in and around Lake Burley Griffin as well as in the ACT and adjoining NSW catchments. These actions are designed to address the health of the Lake in the context of continuing urban growth and climate variability, with the aspiration of achieving progressive and measurable improvements.	In place
ACT Nature Conservation Strategy 2013-23	2013	The Nature Conservation Strategy is a document for all land management, planning, business and community sectors in the ACT to guide a coordinated and integrated approach to nature conservation. The Strategy will help guide future management of the Territory's open spaces, rural areas, urban areas, riverine corridors and nature reserves, and guide investment of funding and resources.	Soon to be updated
ACT Water Strategy 2014-44 Striking the Balance	2014	The ACT Water Strategy provides long term (30 year) strategic guidance to manage the Territory's water resources. The outcomes, strategies and actions incorporate the full breadth of water management activities in the ACT. The ACT Water Strategy is intended to guide the development, integration and implementation of activities undertaken by government agencies (and with ACTEW, Commonwealth, State and Territory agencies), developers, the ACT community, natural resource management groups and other stakeholders involved in planning and water management and water use.	In place
ACT and Region Catchment Strategy 2016–46	2016	The Catchment Strategy sets out the principles for governance, describes the key factors that will affect the catchment over the next 30 years and the actions that aim to optimise outcomes for the region. This strategy will: - provide a vision to all agencies, organisations and individuals involved in catchment management - offer a mechanism to resolve jurisdictional challenges and capitalise on the opportunities for improved catchment management outcomes to manage regional growth - influence and connect to related planning processes - provide a mechanism to develop joint funding bids and prioritise investment and effort for the benefit of the region - reinforce the connections between land and water, rural and urban and interaction between humans and the environment.	In place
ACT Aquatic and Riparian Conservation Strategy and Action Plans	2018	The ACT Aquatic and Riparian Conservation Strategy provides guidance on the conservation of aquatic and riparian areas and component species in the ACT, consistent with the ACT Nature Conservation Strategy 2013–23. This includes managing threats, maintaining and improving ecological connectivity, ecosystem function and biodiversity, undertaking monitoring and research	In place

Policy, Guideline or Plan	Date published	Purpose	Status
		programs, and partnering with the community to support aquatic and riparian conservation.	
ACT Practice Guidelines For Water Sensitive Urban Design	2018	The Practice Guidelines for Water Sensitive Urban Design in the ACT support the General Code and provide developers, ACT Government officers and residents with support on introducing WSUD into their residential lot, streetscape, neighbourhood and estate.	In place
ACT Water Strategy Striking the Balance 2014-44 Implementation Plan Two (2019-23)	2019	The implementation Plan 2 provides a further road map for continuing to address the key actions required to protect the health of our water catchments, to ensure ongoing access to water resources and to ensure the community both enjoys the values of water as well as being engaged in the care and management of the resource.	In place
Water Resources Environmental Flow Guidelines 2019 (No 2)	2019	The Environmental Flow Guidelines are an instrument under the Water Resources Act 2007, that set out the flow requirements (quantity and timing) needed to maintain freshwater ecosystems.	In place
Draft Canberra Urban Lakes and Ponds: Land Management Plan	2019	This Plan aims to: - present the framework guiding the management of Canberra's urban waterbodies in a manner responsive to a range of environmental and community values - communicate management intentions associated with managing Canberra's urban waterbodies - document the management vision, core values and services for Canberra's urban waterbodies - complement other associated plans and strategies - provide performance indicators to monitor the implementation of the Plan.	In place
Stormwater: Municipal Infrastructure Standards 08	2019	Provide stormwater drainage systems design and documentation to meet the following objectives: - Contribute to a sustainable urban environment - Provide safety for the public - Minimise the impacts of flooding on life and property - Stabilise the landform and control erosion - Enhance the urban environment by providing assets of social, environmental and economic value - Protect and maximise the value of aquatic and terrestrial ecosystems within the stormwater system - Enhance water security by minimising the need for irrigation with potable water - Encourage community involvement and connection with country.	In place
Canberra's Living Infrastructure Plan: Cooling the City	2019	This Plan identifies challenges from climate change, urban growth and renewal, and the aging of the urban forest. The Plan provides a response to address these challenges and to enhance Canberra's urban environment.	In place
Waterways Water Sensitive Urban Design General Code.	2020	Water sensitive urban design (WSUD) is an approach to urban planning and design that aims to integrate the management of the water cycle including stormwater into the urban development process which considers integrated water cycle management. The WSUD general code aims to provide the necessary WSUD targets and strategies to be implemented to ensure improved environmental sustainability.	In place
Urban Riparian Corridor Guidelines		To protect and enhance riparian and other values within the urban drainage system of the ACT.	In development

3.1 Urban catchment management

The *ACT Water Strategy 2014-44* provides strategic guidance for the management of the Territory's water supply over the next 30 years. Whilst it is not a catchment strategy, the ten actions forming its first outcome are related to the health of catchments and water bodies (Figure 14). The water quality target outlined for the ACT is that it will *maintain or improve* the quality of water across all ACT managed sub-catchments (30-year target). This includes ACT managed urban catchments entering the Murrumbidgee River. Flow targets are also outlined for urban creeks, natural and modified ecosystems. Modified ecosystems are those that have been modified by catchment activities and changes to flow regime, and include the Murrumbidgee River, Molonglo River and Lake Burley Griffin.

The *ACT and Regional Catchment Strategy 2016-46* on the other hand is explicitly a catchment strategy and operates at a regional scale spanning most areas of the Murrumbidgee River catchment upstream of Burrinjuck Dam and additional lands in the Queanbeyan–Palerang and Yass Valley areas. It is focused on improving high level governance and cross-jurisdictional relationships through the activities of the "ACT and Region Catchment Management Coordination Group". The strategy also does not contain specific biophysical and social catchment targets but recognises that these need to be developed. There are no specific objectives for urban catchments; however, there are actions to provide an integrated catchment management planning approach for growth and settlement patterns in the ACT and Region, and for educating community on catchment health.

OUTCOME 1: Healthy catchments and waterbodies		
Well-managed, functioning aquatic ecosystems that protect ecological values and contribute to the liveability of the ACT community.		
STRATEGY 1: Achieve integrated catchment management across the ACT and region		
Actions	1	Strengthen coordination and collaboration for catchment management across the ACT and region
	2	Enhance knowledge and spatial planning for water and catchment management
	3	Integrate water cycle management and green infrastructure into the planning and design of urban environments
	4	Improve water monitoring and analysis across the ACT and region
STRATEGY 2: Protect and restore aquatic ecosystems in urban and non-urban areas		
Actions	5	Improve water quality and ecosystem health in the ACT and region's rivers, lakes, aquifers, ponds and wetlands
	6	Ensure appropriate management (volume, timing, and quality) of environmental flows
	7	Strengthen compliance and enforcement for water resource management
STRATEGY 3: Manage stormwater and flooding		
Actions	8	Manage stormwater infrastructure sustainably
	9	Improve planning, monitoring and compliance for stormwater management
	10	Improve planning, information and regulation for flood management

Figure 14. *Strategies and actions under Outcome 1 (ACT Government 2014a)*

A key driver for the need for integrated catchment management in the ACT is that there is no overall strategic catchment management setting, plan or policy for agencies to operate against. As outlined in the *ACT Water Strategy*, one of the foundational actions is to establish catchment management arrangements to better integrate water and land management for improved water quality and catchment health in the ACT and region. Related to this, but at an urban scale, is the lack of a strategic approach to stormwater management through a strategy or framework (such as a catchment management strategy). As identified in the *Water Sensitive Urban Design Review* (ACT Government 2014b), both the Environment, Planning and Sustainable Development Directorate and Transport Canberra and City Services state that they have not undertaken catchment-wide planning for stormwater in the ACT. This is despite stormwater being one of the key pressures on the health of urban lakes and waterways in the ACT.

The importance and need for integrated catchment management is well recognised from our review of the key strategies and investigations in the ACT and the need for strategic decision making for the lakes, ponds and waterways has also been well recognised. However, while the *ACT Water Strategy* is implementing actions around integrated catchment management, these generally relate to the high-level coordination of water matters at an ACT and regional scale. To address the pressures on urban lakes and waterways, catchment management and planning is required at an urban catchment scale. A focus on urban catchments is important because there is significant pressure placed by the urban environment on receiving waters including within the urban catchment and also downstream such as the Murrumbidgee River. The impacts on receiving waters are ongoing and will not improve without a concerted and planned effort over time. There is a lot of social value to be gained from improving the condition of urban lakes and waterways as they contribute to community wellbeing.

The need for strategic decision making to address current and future challenges to the lakes is recognised in the Report on the *State of Watercourses and Catchments for Lake Burley Griffin* (Commissioner for Sustainability and the Environment 2012). However, there is currently no governance structure to guide strategic decision making for the lakes. The *Draft Canberra Urban Lakes and Ponds Land Management Plan* (ACT Government 2019c) outlines responsibilities for a range of ACT Government agencies for managing different aspects of the lakes and ponds. However, it does not present a strategic plan by the different agencies to address current and future challenges to water quality, aquatic and riparian health.

Strategic decision-making for the lakes and ponds needs to recognise the multiple roles that they perform and be based on a full understanding of the range of environmental, social and economic values that they provide. For instance, large regional ponds such as Yerrabi Pond and Point Hut Pond which serve to treat stormwater have also become important community assets, and there is an expectation by the community that they will be protected from the impacts of future development in their catchments. It appears that in some contexts they are considered as treatment systems but in others they are considered as receiving waters.

Our investigation more broadly identifies that there is no entity responsible and accountable for catchment-wide planning and management at an urban scale and for making strategic decisions for the lakes, ponds and waterways as part of a connected system. They are not well integrated into strategies and policies. There also appears to be no coordinated management of urban waterways, with reliance on community-based volunteer efforts such as Waterwatch for monitoring and local catchment groups for revegetation.

In light of the above, there is also an opportunity to review the *Water Use and Catchment General Code* (ACT Planning and Land Authority 2009). The purpose of the code is to identify permitted water uses and environmental values in the waters of the ACT and to identify the water quality and streamflow criteria for protection of these uses and values. There is an opportunity to better articulate the environmental and social values and roles of urban lakes, ponds and waterways in this Code, including requirements for water quality and flows, and to better link this Code with the *Waterways WSUD Code*. This was also outlined in the *Water Sensitive Urban Design Review* (ACT Government 2014b).

Key findings:

- ACT Government policies and strategies do not address integrated catchment planning and management across existing and potential future urban catchments.
- There is currently no clear governance structure to guide strategic decision-making for protecting and improving the health of urban lakes and waterways in the ACT.
- There is a need for stakeholders to recognise the multiple roles that lakes and ponds perform and fully understand their objectives and the range of environmental, social and economic values that they provide.
- The *Water Use and Catchment General Code* does not articulate environmental and community values of urban lakes, ponds and waterways including requirements for water quality and flows. There is poor linkage of this code with the *Waterways WSUD Code* and the *Canberra Urban Lakes and Ponds: Land Management Plan.*

Recommendations:

Consideration should be given to the following:

- Establishing an entity that is responsible and accountable for integrated catchment management at the urban and peri-urban scale and for making strategic decisions for the urban lakes, ponds and waterways including stormwater management in the ACT.

- Developing a long-term funding strategy to support the activities of the proposed entity based on revenue collected from the ACT Water Abstraction Charge (WAC).
- Aligning the activities of the proposed entity to the 10 actions under the "*ACT Water Strategy* Outcome 1 – Healthy catchments and waterbodies".
- Reviewing the *Water Use and Catchment General Code* to reflect environmental and community values of urban lakes, ponds and waterways including requirements for water quality and flows.
- Better linkage between the *Water Use and Catchment General Code*, the *Waterway WSUD code* and the *Canberra Urban Lakes and Ponds: Land Management Plan*.

3.2 Aquatic and riparian ecosystems

The *ACT Aquatic and Riparian Conservation Strategy and Action Plans* (ACT Government 2018a) provides guidance on the conservation of aquatic and riparian areas and component species in the ACT, consistent with the *ACT Nature Conservation Strategy 2013–23* (ACT Government 2013). The objectives of the strategy include the provision of conservation management guidelines for the protection and enhancement of aquatic and riparian areas primarily in natural water bodies; and the identification of threats to aquatic and riparian ecosystems, providing guidelines for their management.

However, urban lakes, ponds and waterways are not specifically covered in *ACT Aquatic and Riparian Conservation Strategy*. Whilst it covers the Molonglo and Murrumbidgee Rivers, it does not cover wetlands nor urban waterways such as the Queanbeyan River, Tuggeranong, Weston, Yarralumla, Sullivans, Woolshed, Jerrabomberra and Ginninderra creeks. Riparian zones surrounding artificial lakes, large floodplain areas or substantially modified urban water courses are also excluded. A key feature of urban waterways in the ACT is the engineered nature of the system which has virtually eliminated any habitat values and reduced the landscape value. In general, the physical form of urban waterways in the ACT tend to transition from highly modified concrete channels in highly urbanised areas, to concrete swales with grassy banks in mid-reaches, to more "natural" but disturbed sections in upper reaches. Rehabilitation of urban waterways is an opportunity to not only improve aquatic and riparian ecosystems, but also improve amenity, reduce bed and bank erosion and sediment loads downstream, and incorporate stormwater treatment and retention features. Waterway restoration will need to take different forms in different parts of the catchment to reflect the opportunities and constraints. This strategy is highly relevant to urban waterways and water bodies because these urban parts of the catchment are the source of a range of threats and impacts on highly valued downstream waterways.

The *ACT Aquatic and Riparian Conservation Strategy* recognises that urbanisation has led to reduced water quality and modified flows, creation of barriers, increased pest animals and weed invasion, increased fishing pressure, removal of in-stream large woody debris and modification of riparian zones to meet recreational and urban expectations. The strategy provides high-level guidance on managing a range of interacting threats relevant to the health and function of both urban and non-urban waterways, including:

- Urban land use impacts
- River regulation and water extraction
- Water quality, turbidity and in-stream sedimentation
- Thermal pollution
- Riparian zone modification
- Weeds, pest animals, parasites and diseases
- Barriers to connectivity for aquatic populations
- Inappropriate fish harvesting
- Climate change

Guidance from across a number of these interacting threats (urban land use impacts, sedimentation, turbidity, and water quality) is important to manage the effects of urban areas and urban development on aquatic and riparian health. Key guidance includes:

- Plan and design urban areas to minimise urban edge impacts on adjacent riparian and aquatic areas
- Use best practice WSUD, including sediment ponds, building phase sediment and erosion controls and adequate buffer width between urban and riparian zones
- Manage sites adjacent to aquatic and riparian areas to reduce weed invasion and pest animals
- Manage recreational activities in the riparian zone to minimise impact using measures such as providing non-erodible walking paths where high intensity recreation occurs
- Educate residents about waterway health, including stormwater run-off, recreational fishing and illegal flora and fauna introductions
- Ensure a vegetated buffer strip between urban and riparian zones to filter and trap sediment
- Use sediment and erosion control measures in urban areas and during construction activities
- Carry out catchment and riparian revegetation where necessary.

However, it appears that the high-level guidance is not being applied in relation to urban development planning and construction. This was highlighted in Alluvium's investigation into the future development opportunities and constraints in the Western Edge Investigation Area (Alluvium 2020). The investigation showed that stormwater management needs to consider erosion from the transfer of excess flow volumes from urban areas above the Murrumbidgee and Molonglo Rivers down the escarpments and into these receiving waters. In the Lower Molonglo River, many stormwater discharge points from the Coombs, Denman and Molonglo developments stop at the Molonglo River reserve boundary resulting in flow transmission issues inside the Reserve that typically include erosion and sedimentation. Water quality and weed infestation issues may also arise over time. These discharge points now require treatment, potentially including options such as level-spreaders, rock-lined waterways, engineering drainage structures and the use of appropriate vegetation to stabilise discharge areas and manage flows.

To avoid or minimise impact, stormwater management principles should consider minimising impervious areas and enhancing permeability elsewhere; reducing the hydraulic connectivity of the stormwater system by the use of swales, vegetated waterways, wetlands and ponds rather than pipes and lined channels; and incorporating detention and retention capacity (e.g., reuse, infiltration and evaporation/evapotranspiration, retarding basin measures). These principles need to be translated into policy that informs urban development construction.

Key findings:

- *ACT Aquatic and Riparian Conservation Strategy* covers the Molonglo and Murrumbidgee Rivers but not urban tributaries to these rivers and urban lakes and ponds. As such, there is no clear strategy for protecting and enhancing aquatic and riparian health of urban waterways and lakes.
- Land development is having a direct impact on the aquatic and riparian health including in the Molonglo and Murrumbidgee Rivers. This is arising from poor erosion and sediment control practices during construction, and limited guidance (and lack of application of existing guidance) on design of stormwater discharges at the urban edges.
- The *ACT Aquatic and Riparian Conservation Strategy* provides detailed guidance on a number of interacting threats that occur in urban areas (and therefore does have relevance to addressing urban water quality and aquatic and riparian health) but is not being adequately applied to new developments.

Recommendations:

Consideration should be given to the following:

- Developing an urban aquatic and riparian strategy as part of the urban catchment management strategy to protect and enhance the condition of aquatic and riparian environments in existing urban and urbanising areas. Guidance from the non-urban *ACT Aquatic and Riparian Conservation Strategy* could be used to inform an urban aquatic and riparian strategy with a view to improving water quality from urban areas.

- Developing an urban buffer Land Use Zone adjacent to the Molonglo and Murrumbidgee River corridor zones that allows sufficient space to mitigate high stormwater flows that avoids any requirement for engineered structures within the river corridor reserves themselves.
- Developing a program to rehabilitate urban waterways including:
  - Naturalisation of concrete channels in the lower reaches
  - Naturalisation of concrete swale and grassy banks in the mid reaches
  - Rehabilitation of disturbed reaches in the upper catchment where greenfield developments are proposed.

3.3 Water quality and flow

3.3.1 Water quality

The *ACT Water Strategy* provides a target to maintain or improve water quality across all water sources, and within all catchments and sub-catchments. The indicator related to this target is outlined below:

> *AUSRIVAS performance classifications for select reaches of major rivers are maintained or improved. The level of nutrients, organic material and sediment loads entering the ACT reach of the Murrumbidgee River is no greater than from a well-managed rural catchment.*

The strategy also has an interim target for a measurable improvement in catchment health in areas (sub-catchments) that receive funding for on-ground works from the ACT Basin Priority Project (Commonwealth funded, 2014-2019). The indicators related to this interim target are outlined below:

- Median Total Phosphorus load from urban catchments less than 20 kg/km^2/yr.
- Median Organic material (measured as TOC) load from urban catchments less than 500kg/km^2/yr.
- Median Suspended Solids load from urban catchments less than 10,000 kg/km^2/yr.

Assessment by Alluvium Consulting of future development opportunities and constraints in the Western Edge Investigation Area (Alluvium 2020) showed that if the mandated “development targets” for stormwater treatment in the *Waterways WSUD code* are applied at a site changing from a “well-managed rural catchment” to a predominantly urban catchment, there is an increase in pollutant loads (TSS, TP and TN) leaving the site compared to pre-developed condition. This is based on MUSIC[1] modelling undertaken for the project with underlying assumptions on pollutant load generation in urban and rural catchments. Export loads from the site also do not meet *ACT Water Strategy* interim targets for urban catchments for Total Phosphorus and Total Suspended solids.

The implication of this is that there will be an increase in pollutant loads entering receiving waters, including the Murrumbidgee River, if regional projects for stormwater treatment are not undertaken in addition to development site projects. Interim targets can be met if “regional targets” under the *Waterways WSUD code* are applied. However, even when regional targets are applied, there remains an increase in loads compared to pre-developed condition (i.e., a well-managed rural catchment). Depending on the downstream pond or lake, this can be an issue if the objective is to improve water quality.

This example highlights that it is important to develop an urban catchment strategy that outlines how the “development” and “regional’ targets will be applied in practice to meet objectives for urban lakes, ponds and waterways and, ultimately, the Murrumbidgee River. To mitigate against untreated stormwater entering receiving waters, it may be prudent to mandate stormwater quality treatment in all catchments within which urban development is planned, irrespective of whether water quality targets can be met by treating only a subset of catchments.

[1] MUSIC is short for Model for Urban Stormwater Improvement Conceptualisation. It is a software designed to simulate rainfall and pollution generation to enable strategies to be developed for managing hydrology and pollution impacts arising from urban stormwater runoff.

In addition, current policy under the *ACT Waterways: Water Sensitive Urban Design (WSUD) General Code* (ACT Government 2020) requires stormwater detention measures are provided in new residential developments and that the peak rate of stormwater runoff from the estate does not exceed the peak rate of runoff from an unmitigated (rural) site of the same area for minor and major (1% AEP) storms. This Code does not fully consider the potential for erosion under different flow management scenarios. A range of flow metrics are often used to assess changes in flow regime as a result of development and urbanisation, which often increases the erosion potential within waterways. One method is the Erosion Potential Index (EPI).

The EPI explicitly considers the magnitude and duration of flows above a threshold to estimate the time-integrated sediment transport and scour characteristics across a range of flows and time periods for different flow management scenarios, rather than peak flows predicted to occur with a particular frequency. The continuous simulation EPI approach therefore provides a more realistic estimate of the effective work carried out on a channel by flow, especially when the hydrologic model is calibrated to recorded flows.

Scenario modelling and mitigation measures to ensure that any development results in an EPI of unity would mean there is unlikely to be a major change in channel trajectory as a result of the development. A good understanding of the actual critical shear stress in the channel is still required, as well as an understanding of the active geomorphic processes within the area of study.

3.3.2 Flow

The *ACT Water Strategy* provides flow targets and indicators as follows:

- In the case of urban creeks, aim for reduction in the intensity and volume of urban stormwater flows so that the runoff event that occurs on average once every three months, is no larger than it was prior to development.
- In the case of natural ecosystems and modified ecosystems, protect base flow, riffle and channel maintenance flows, and special purpose flows in accordance with the *ACT Environmental Flow Guidelines* (ACT Government 2019b).

The *Environmental Flow Guidelines* point to the following flow requirements as applicable to urban catchments:

Modified ecosystems (Murrumbidgee River, Molonglo River and Lake Burley Griffin):

- *Lake Burley Griffin*: Allow water level fluctuations of up to 0.6 m below full supply level. Limit drawdown to 0.2 m July-November (to protect waterbird breeding).
- *Other modified reaches:* Protect baseflow and channel maintenance flows by:
  - Maintain 80th percentile monthly flow in all months to protect baseflow. The base flow is defined as the modelled natural 80th percentile of stream flow.
  - Abstraction will be restricted to a long-term average of 10% of the flow above the 80th percentile flow (this is to protect channel maintenance flows).

Urban ecosystems:

- *Urban streams*: In all months in all years the base flow is to be protected. In addition, abstractions of surface water may never cause cessation of flow in a stream. Flooding flows, particularly channel maintenance flows, are to be protected by restricting abstraction in water management areas to 10% of the flow volume above the 80th percentile.
- *Urban lakes, ponds and wetlands:* Allow water level fluctuations of up to 0.6 m below full supply level, where possible. Limit drawdown to 0.2 m July-November

The *Environmental Flow Guidelines* also recommend that flows in urban streams be restored to natural flow regimes as far as practicable, while recognising that it is unlikely that streams will return to the pre-development 'chain of ponds' condition.

The *ACT Aquatic and Riparian Conservation Strategy* refers to a number of shortfalls in the implementation of environmental flows in the Molonglo and Murrumbidgee Rivers. For example, there are no dedicated environmental flow releases from Lake Burley Griffin due to the National Capital Plan specifying protection of the visual and symbolic role of the lake and Scrivener Dam not being designed to enable such releases. The Strategy guidance relating to flows includes:

- Investigate feasibility of dedicated environmental flow releases from Lake Burley Griffin (negotiate possibility with the National Capital Authority).
- Monitor ecosystem response to environmental flows (are flows sufficient to maintain ecosystem function and aquatic species?).
- Monitor riparian zones (are flows sufficient to keep riparian communities intact?) and determine whether provisions for maintaining riparian vegetation communities are needed in the E*nvironmental Flow Guidelines*.

The *ACT Waterways: WSUD General Code* has a stormwater retention objective. However, the drivers for this objective appear to be more for mains water use reduction and pollutant load reduction rather than meeting a flow objective in receiving waters. For instance, the stormwater retention requirement in the Code is expressed as a storage capacity and reuse requirement (1.4 KL per 100 m^2 of total impervious area) which if implemented to meet household internal end-uses only (and no infiltration) does not contribute to protecting baseflow in waterways. The "reuse" term should be defined so that it can be applied to meet a range of objectives.

3.3.3 Water quality and flow monitoring

We have identified that a reasonable amount of data is being or proposed to be collected in terms of water quality and waterway condition indicators including:

- Macroinvertebrate monitoring undertaken using the AUSRIVAS protocol. It involves collecting samples of stream invertebrates from stream edge sites in the ACT region during spring and autumn, including in urban waterways (ACT Government 2016b)
- Water quality surveys, macroinvertebrate surveys and riparian condition surveys by Waterwatch as part of the Catchment Health Indicator Program 2020 report (Upper Murrumbidgee Waterwatch 2020) which include urban waterways and ponds.
- Via the Integrated Water Quality Monitoring program which is understood to be proposing monitoring activities to fill identified gaps.

As identified in the *ACT Water Strategy*, there is a need for a more integrated and coordinated approach to water monitoring in the ACT. In urban catchments, we also identify that a more coordinated approach to monitoring environmental values, flows and water quality is required including in identifying gaps and undertaking additional monitoring. We also observe that the ACT Government is relying heavily on community-based volunteer efforts such as Waterwatch for this monitoring. Interviews with water professionals in the ACT indicate the longitudinal based flow monitoring system currently implemented by the Waterwatch program needs to be complemented by event-based monitoring (Thukten 2019).

Our recommendation is to consider prioritising the following sub-actions under the *ACT Water Strategy* Action 4 – Improve water monitoring and analysis across the ACT and region – in urban catchments:

- Better integration of Waterwatch and AUSRIVAS activities into a broader monitoring program.
- Identify priority gaps in monitoring and undertake additional monitoring.
- Monitor existing infrastructure for performance and establish monitoring and design guidelines for future infrastructure, e.g., ponds and wetlands.
- Improve access to water monitoring data, including by stakeholders.

Key findings:

- Flow and water quality objectives for the receiving waters (e.g., lakes and waterways) in the urban catchments are not well defined for social and environmental values
- Stormwater quality targets and stormwater retention targets in the *Waterways WSUD code* are not tied to environmental outcomes in the receiving waters.
- There is no catchment strategy that outlines how "development targets" and "regional targets" for stormwater treatment will be applied in practice to improve conditions in urban lakes and waterways

and meet objectives for the Murrumbidgee River. Stormwater quality targets may not be sufficient to avoid an increase in pollutant loads from greenfield developments entering urban lakes and ponds.

- The *ACT Waterways: WSUD General Code* does not fully consider the potential for erosion under different flow management scenarios.
- There is a need for more coordinated approach to monitoring environmental values, flows and water quality in urban lakes, ponds and waterways.
- The ACT Government appears to be relying heavily on community-based volunteer efforts such as Waterwatch for this monitoring.

Recommendations:
Consideration should be given to the following:

- Developing flow and water quality objectives for urban lakes, ponds and waterways. The objectives should build on previous scientific studies, the *Environmental Flow Guidelines,* and the *Canberra Urban Lakes and Ponds: Land Management Plan*. Where knowledge gaps on environmental values exist, detailed field assessment should be undertaken to improve the state of knowledge (in addition to the data collected by Waterwatch).
- To mitigate against the possibility that assumptions in MUSIC around the homogeneity of pollutant loads within a land use class fail, it may be prudent to mandate stormwater quality treatment in all catchments within which urban development is planned, irrespective of whether water quality targets have already, notionally, been met.
- Scenario modelling and mitigation measures to ensure that any development results in an EPI of unity would mean there is unlikely to be a major change in channel trajectory as a result of the development. A good understanding of the actual critical shear stress in the channel is still required, as well as an understanding of the active geomorphic processes within the area of study.
- Prioritising Action 4 of the *ACT Water Strategy* – Improve water monitoring and analysis across the ACT and region – in urban catchments including:
  - Better integration of Waterwatch and AUSRIVAS activities
  - Identifying priority gaps in monitoring and undertake additional monitoring for urban catchments
  - Monitoring performance of existing WSUD, including ponds and wetlands, with the aim of improving design guidelines for future infrastructure.
- We understand that an Integrated Water Quality Monitoring Program is proposed in the *ACT Water Strategy Implementation Plan Two* (ACT Government 2019a) and that it will be proposing monitoring activities to fill identified gaps. We recommend that it considers:
  - Identifying monitoring gaps in urban catchments
  - Undertaking additional water quality and flow monitoring in urban lakes, ponds and waterways
  - Undertaking assessment of water treatment performance of WSUD assets such as constructed wetlands.
  - Providing improved access to monitoring data, including collected as part of the Program.

3.4 Water Sensitive Urban Design

Water Sensitive Urban Design is defined in the *Waterways and WSUD General Code* as:

> *an approach to urban planning and design that aims to integrate the management of the water cycle including stormwater into the urban development process which considers integrated water cycle management.*

The *Waterways WSUD General Code* makes provisions for implementation of WSUD in development and redevelopment on sites across all zones of the *Territory Plan (*. It stipulates the outcomes sought in relation to water sensitive urban design primarily through a series of targets for mains water reduction, water quality and stormwater quantity as well as permeability requirements and endorsement of an operation and maintenance plan for assets that are handed over to ACT Government.

Key findings and recommendations:
The *Water Sensitive Urban Design Review* (2014) identified issues with the legislative framework and proposed eight priority projects to address the issues (Figure 15). We support the 8 priority projects and recommend commitment and ongoing implementation of these priority projects by the ACT Government noting that the first priority project – code revision supported by practice guidelines – has been completed. The findings and recommendations of the Marsden Jacobs and Associates 2015 report – Alternate Management and Funding Models for Sustainable Operation and Maintenance of Sustainable Water Quality Assets should be reconsidered.

Recommendations

The recommendations and actions can be grouped together as priority projects to ensure they are delivered to meet the government's commitment to this inquiry. All priority projects consider the information that the issues addressed and the recommendations in section 6.

Priority Project 1: Code restructure and revision

EPD leads a revision of the water sensitive urban design provisions in the Territory Plan, supported by a practice guideline to provide for greater clarity and consistency in interpretation as well as to promote innovation and increase flexibility in meeting WSUD targets.

Priority Project 2: Alternative management and funding models

EPD, Territory and Municipal Services Directorate (TAMS), Chief Ministers, Treasury and Economic Development Directorate (CMTEDD) work together to investigate alternative management and funding models for sustainable maintenance of WSUD assets, informed by cost-benefit analysis.

Priority Project 3: Housing affordability

The ACT Government will encourage WSUD approaches that maximise cost efficiency at the appropriate level (e.g. on-site versus sub-catchment) to minimise impacts on housing affordability in the ACT, as well as the maintenance burden.

Priority Project 4: Green infrastructure strategy

EPD, subject to available funding, lead development of a green infrastructure strategy for the ACT as a means of realising the social, economic and environmental values of our green assets including the integration of WSUD assets.

Priority Project 5: Design standards

TAMS, subject to available resources, continue its review of design standards for urban WSUD and related infrastructure.

Priority Project 6: Modelling and monitoring

EPD leads the development of a water quality and flows modelling and monitoring program, focusing on understanding the performance of WSUD assets against modelled results and building internal capacity within the ACT Government in modelling and monitoring.

Priority Project 7: Erosion and sediment control

EPD, through the ACT Environment Protection Authority, review the Environment Protection Guidelines for Construction and Land Development in the ACT (2011) and continue to work with the construction industry to improve their performance in erosion and sediment control during the building construction phase. EPD also investigate building certifiers to ensure compliance with site management requirements, including erosion and sediment control.

Priority Project 8: WSUD asset management transfer

CMTEDD leads the development of a guideline in consultation with TAMS to inform the effective transfer of government owned WSUD infrastructure from construction to management.

Figure 15. *Priority projects identified in the Water Sensitive Urban Design Review (2014)*

We have made the following observations regarding the revised *Waterways and WSUD General Code* and the practice guidelines:

- For green/living infrastructure element, the rule requires a minimum 20% of the site to be permeable. This target is likely being achieved under business-as-usual practices. It does not align with the *Living Infrastructure Plan*'s target of 30% permeable surfaces in Canberra's urban footprint by 2045.
- With regards to the mains water use reduction target, an increase in the mains water use reduction target from 40% to 50% of pre-2003 levels in all new developments and redevelopments is considered feasible. An intermediary target, such as 45%, may be appropriate also. This is due to improvements in recent years in the efficiency ratings of household plumbing fixtures and appliances, the potential for inclusion of flow restrictors on outdoor plumbing fixtures, and the potential to increase roof water collection area requirements.
- We note that in the guidelines, the objective for redevelopment and infill projects is to achieve a net improvement in water quality outcomes by application of identical targets as greenfield developments, with the idea that this will progressively improve water quality discharged from existing urban areas as part of the urban renewal process. The code makes provision for a stormwater management offset scheme when works are technically unfeasible or prohibitive in cost. However, it is acknowledged in the guidelines that the ACT Government does not currently have a stormwater management offset scheme and that developers must consult the ACT Government about any offset proposal.
- There is an action in the *ACT Water Strategy* to integrate water cycle management and green infrastructure into the planning and design of urban environments. It is important the WSUD code and guidelines are updated over time to align with the recommendations from the ACT *Living Infrastructure Plan* and the "holistic water cycle management plan" which is scheduled to be developed in 2020-21 as per the Implementation Plan Two (ACT Government 2019a) of the *ACT Water Strategy*.

3.5 Cost effectiveness of Water Sensitive Urban Design infrastructure

The Environment, Planning and Sustainable Development Directorate undertook an economic evaluation of the *ACT Healthy Waterways* program in 2019 which included assessing the cost-effectiveness (i.e., value for money) of each of the 20 WSUD assets constructed under the program to improve water quality (through reductions of TN, TSS and TP) and a cost-benefit analysis (CBA) of broader program measures (Natural Capital Economics, 2019).

On average, the assets under this program were determined to be cost-effective at managing TN and TSS with an average cost-effectiveness of $303 per kilogram of TN and $2 per kilogram of TSS. This was under the average cost-effectiveness figures in other jurisdictions estimated by Water by Design (2014) and Alluvium (2017) at $474 and $2 per kilogram respectively. The program's assets were found to be, on average, less cost-effective at managing TP ($1,827 per kilogram) compared with other jurisdictions ($1,188 per kilogram on average). Some assets were found to deliver lower cost-effectiveness across all three pollutants compared to average of estimates in other jurisdictions. Reasons included that some projects were not primarily undertaken for water quality (e.g., waterway restoration project which consisted primarily of riparian plantings above the waterline) or a scaled back nature of some of the assets due to the discovery of historical or cultural significance at the sites. However, poor water quality outcomes alone should not be taken as evidence of poor overall economic performance.

The CBA considered the full suite of economic benefits based on benefits and values identified within an ecosystem services framework. The total benefit was estimated based on:

1. avoided costs from pollution load reductions/abatement,
2. load reductions attributable to the behaviour change initiatives (funded through the H2OK program),
3. avoided loss in recreational values from lake closures due to algal blooms,
4. improved amenity and local recreation for residents living in proximity to assets,
5. benefits from urban cooling and

6. non-asset specific benefits attributable to the improved understanding of water quality impacts from the program's research, monitoring and evaluation.

The quantified benefits were assessed against the total costs of the program, which included the capital, ongoing operating and maintenance, and non-infrastructure costs relating to research, monitoring, program management and the behaviour change (H2OK) program. The results from the CBA indicated that based on a 30-year appraisal period, the program is economically viable with a net present value (NPV) of approximately $50 million and a benefit-cost ratio of 1.66. The analysis found that the avoided abatement costs expectedly garnered the greatest proportion of the total benefits, followed by the benefits from improved amenity and recreation. However, it should be noted that the valuation of benefits other than pollution abatement were heavily assumption-driven, in absence of primary study. As such, these estimates for some benefits—particularly recreation, amenity and urban cooling—could have been conservative or understated.

The benefits expected from behaviour change were very low owing to conservative assumptions for change applied in the CBA. The H2OK program, which funded behaviour change activities within the *ACT Healthy Waterways* Program, was designed to encourage positive behaviour change among ACT residents to reduce stressors (e.g., disposal of leaves and grass clippings) to waterways through improving waterway literacy. The program included a range of activities including print, radio, online and social media campaigns, tours of demonstration sites, and roadshow and education events.

In the early 2000s, the NSW Government placed a strong emphasis on behaviour-change through its Urban Stormwater Education Program (USEP) as a means of reducing the negative impacts of stormwater. Similar to H2OK, USEP used the media to change people's behaviour, although with a higher budget of $4 million, its campaign used mass media as well as social media and had a larger reach. These initiatives led to measured increases in people's efforts to reduce behaviours that would pollute stormwater. An evaluation of USEP found 2.1 million people reported changes in their behaviour to avoid actions that would pollute stormwater since its introduction (32.3% of the total resident population of NSW in the year 2000). Although the evaluation report for the NSW initiative did not investigate whether such changes were maintained, if the H2OK Program has an impact similar to the USEP campaign, it would equate to up to 136,900 ACT residents changing their behaviour to avoid actions that would pollute waterways. However, given the difference in the campaigns, this assumption was deemed not to be appropriate for the CBA as only 2.6% of residents in the ACT surveyed following three years of the H2OK Program reported to have acted as a result of the program, considerably smaller than 32.3% from the NSW USEP campaign. The preliminary H2OK Program evaluation results were deemed more appropriate for the CBA and used to estimate the likely Program benefits.

Key findings:

- From a pollution abatement perspective, the investigation found that WSUD assets constructed under the *ACT Healthy Waterways* program were cost-effective at managing TN and TSS when compared to average of estimates in other jurisdictions, but less cost-effective at managing TP. Some assets constructed under the *ACT Healthy Waterways* program were found to be less cost effective in terms of pollution abatement compared to average of estimates in other jurisdictions.
- From a cost-benefit analysis (total benefits assessed against total costs), the investigation found that the *ACT Healthy Waterways* program is economically viable with a net present value (NPV) of approximately $50 million and a benefit-cost ratio of 1.66 based on a 30-year appraisal period.
- Pollution abatement costs garnered the greatest proportion of the total benefits, followed by the benefits from improved amenity and recreation. However, valuation of benefits other than pollution abatement were heavily assumption-driven in absence of primary study.
- The benefits expected from behaviour change were very low owing to the conservative assumptions for change applied.

Key recommendations

Consideration should be given to the following:

- Cost-effectiveness analysis for WSUD investments prior to allocation of funds to improve decision-making in selection of projects and sites and in maximising total potential benefits from program planning. Assessment of project risks should consider impact on cost-effectiveness should certain risks eventuate.

- Cost-benefit analysis in conjunction with a cost-effectiveness analysis to give transparent metrics for funding allocation and enhance communication of decision-making with stakeholders.
- Undertaking primary studies to better understand the range of ecosystem service benefits derived from WSUD investments such as biodiversity improvement, urban cooling and recreation. Better understanding of these benefits will improve assumptions used in cost-benefit analyses. Consideration of all benefits within a CBA framework can also improve the messaging around WSUD investments.
- Education initiatives for similar programs in the future to improve behaviour changes. The benefit of lasting behaviour changes is that it can reduce the need for large WSUD asset investments in the long term.

4 Evaluation of planning decision and development assessment processes that may impact water quality

In this section, we report on the evaluation of the development approval process with regards to Water Sensitive Urban Design infrastructure in new developments. The evaluation covers the planning stage of the WSUD infrastructure life cycle which is key stage over the course of the development approval process. The evaluation of other stages of WSUD infrastructure (design, construction, establishment, and operations and maintenance stages) are covered in section 5.

The findings are based largely on:

- The findings of the ACT Auditor-General's Report on Acceptance of Stormwater Assets (ACT Audit Office 2018) – An audit which found deficiencies in the acceptance of stormwater assets and the management of accepted assets. All but one recommendation was agreed and incorporated into the actions of the *ACT Water Strategy Implementation Plan Two* (ACT Government 2019a).
- Review of the *ACT Practice Guidelines for Water Sensitive Urban Design* (ACT Government 2018b) which is intended to be used to assess development applications and outline the relevant requirements to intending applicants in designing development proposals and preparing development applications.
- Findings of an audit of WSUD assets in the ACT in 2015 (Alluvium 2016), which included interviews with relevant ACT Government staff, asset inspections and asset performance monitoring.

The *ACT Practice Guidelines for Water Sensitive Urban Design* is a supporting document to the Waterways WSUD general code. It helps to explain the planning provisions set out in the WSUD Code, and to provide guidance and options for compliance with the code. The guidelines are intended to be used to assess development applications and outline the relevant requirements to intending applicants who are designing development proposals and preparing development applications. The Guidelines will assist in keeping the design and planning process of WSUD assets transparent. This is because in the past the quality of WSUD design and the level of service obtained from constructed assets have varied which partly originated from poor documentation and lack of transparency in the planning and design stage.

Module 2 of the guidelines include steps to be undertaken during the planning stage, design stage and delivery stage (construction, establishment, handover) and maintenance stage. Our examination of the guidelines is that it is a step in the right direction in providing greater clarity at each stage. At the planning stage, steps are outlined for developing a WSUD strategy with the intent that a WSUD outcome plan and stormwater masterplan is submitted to EPSDD for approval. The Guidelines document provides a typical table of contents for the report and requests that the strategy is reported against the required objectives of the ACT WSUD code supported by numerical modelling which will be audited by the Development Assessment Team. It is beyond the scope of this project to understand how well this process is being implemented existing issues and weaknesses. We recommend interviews with the development assessment teams.

During the development application process, EPSDD is the organisation that approves the application. There is a process for EPSDD to seek input from various entities such as TCSS including response to the proposed solutions in terms of maintenance. EPDSS does not need to refer the application to an entity if it is satisfied that the applicant has sufficiently consulted the entity (e.g., prior to the development application), or if the entity has agreed in writing to the proposed development (see finding 3.6 in the Auditor-General's report). However, finding 3.9 of the Auditor-General's report suggests wider consultation across TCCS would have been desirable on some occasions at the development application stage.

As part of Alluvium WSUD Audit project, a number of observations and issues were identified with the broader process from development approval to handover:

- Stormwater quality outcomes could change significantly between development approval and asset acceptance and this would not be picked up in the process.

- Poor concepts, designs and constructed outcomes can be approved at each stage of the process resulting in assets being in poor condition at handover (e.g., without vegetation being well enough established) e.g., Mabo Boulevard swale, Emu Bank wetland.
- Potential maintenance issues are not picked up until handover is complete

A number of reasons may explain why these issues arise:

- It is possible that consultation during the development application and design review stages does not cover all the required entities in the ACT Government (or teams within the relevant entities). We were not able to examine this in more details within the scope of this project and it is possible that development of a stakeholder mapping and engagement process is needed for each stage of the WSUD asset life cycle to assist with this.
- A lack of capacity hinders the ability of staff to undertake meaningful review during development application and design review stages.
- Input from maintenance staff is not always sought at the design review stage. When maintenance staff do provide comments at the design stage, they report that their concerns are not adequately addressed (for example the GPT at Lyneham pond).

It is worth noting that both EPSDD and TCCS have documented the development application process and asset acceptance process and they are consistent (Finding 3.7 in the Auditor-General's report). The report outlines that the roles and responsibilities of agencies involved in the stormwater asset acceptance process are clearly articulated. EPSDD is responsible for approval of development applications. Following the development approval, TCCS is responsible for asset design approval and asset acceptance at handover. We understand that a guideline was to be developed to inform the effective transfer of government owned WSUD infrastructure from construction to management (*Water Sensitive Urban Design Review* report Priority Project 8). If this has occurred, it is a step in the right direction, though the focus is on the final step in the handover process (from construction to asset acceptance) and some of the issues noted above arise much earlier in the process.

However, the Auditor-General's report does note that:

"*an agency-focused negotiation process currently determines what design is to be used and consequently what asset is accepted. This needs to be replaced with a process that focuses on the ACT Government's stormwater objectives, so that optimal stormwater solutions are achieved. Not having this process carries the significant risk that accepted assets may not achieve the ACT Government's stormwater objectives, as articulated in legislation and policy*"

The report also states:

"This is due to TCCS strong focus on adopting the least cost option for maintaining those assets and not necessarily the most appropriate stormwater management solution. In many cases, the optimal solution (achievement of stormwater objectives in a cost-effective manner) is likely to require higher operation and maintenance costs. This requires that different options for financing the operation and maintenance of the assets be considered at the design stage."

This issue is partly related to a lack of strategic approach on stormwater management in the ACT, as discussed in Section 3 above, and limited resourcing for operations and maintenance of WSUD assets. Catchment-wide planning to inform stormwater management objectives and communication of these objectives to all agencies will help to address this issue. Explicit consideration of operations and maintenance (and financing) of proposed assets at the planning and design stage is also important.

Key findings:

- As outlined in the Auditor-General's Report on Acceptance of Stormwater Assets (ACT Audit Office 2018), an agency-focused negotiation process currently determines what design is to be used and consequently what asset is accepted. This process is not necessarily tied to stormwater management objectives and environmental outcomes.

- It is possible that consultation during the development application and design review stages does not cover all the required entities in the ACT Government (or teams within the relevant entities), particularly if initial plans and designs are amended. This means that possible issues, for instance with maintenance, may not be picked up early enough in the process, if at all.
- Sometimes, a lack of capacity or capability hinders staff from undertaking meaningful review at development application and design review stages.

Recommendations:

Consideration should be given to the following:

- Developing a stakeholder consultation plan to ensure the right stakeholders are consulted at each stage of the WSUD asset life cycle, including in repeat cycles. The consultation process should begin in the strategic planning phase with early establishment of operation and maintenance requirements.
- Continuing to build capacity in WSUD asset delivery within the ACT Government.
- Occasional external audits to assess processes at each stage of the WSUD life cycle including development approval, asset design approval and asset acceptance processes.

5 The effectiveness of compliance activities and regulation in protecting waterways and riparian zones

In this section, we report on the compliance and management activities with regards to land development and construction and installation, establishment and on-going operations and management of stormwater management infrastructure both in the public and private realm.

5.1 Compliance with erosion and sediment controls

The quality of erosion and sediment control is known to be highly variable during the estate development phase (e.g., poor erosion and sediment control has been an issue at Coombs) and virtually non-existent during the house-building phase in the ACT. In the lower Molonglo reach where existing environmental values are better documented than other urban creeks (see section 2), values such macroinvertebrates, Platypus and Murray Cod are under threat as result of poor land development practices. There are observations of high turbidity in the tributary of Deep Creek likely caused by land development in the suburb of Whitlam (Upper Murrumbidgee Waterwatch 2020).

Poor erosion and sediment control during land development also has a significant impact on stormwater treatment assets that have been put in place before house-building has started in a development, or where a new estate is later developed in the catchment somewhere upstream of the asset. As described in the Ombudsman report, it is regularly reported that stormwater treatment assets are damaged or compromised by building and other construction activity with heavy siltation in the assets often reported as a key issue. The *Environmental Protection Guidelines for Construction and Land Development* guidelines requires developers and builders to put erosion and sediment controls in place and to be responsible for the damage they cause, all agencies consulted during the course of the audit accepted that there is limited enforcement of the obligations placed on developers and builders. Interviews with water professionals in the ACT echo this, indicating lack of enforcement is a major issue for water quality in the ACT (Thukten 2019).

The *Environmental Protection Guidelines for Construction and Land Development* provides guidance on preferred methods for pollution control design, construction operation and maintenance during construction and land development activities to protect the environment. In terms of erosion and sediment control, the guidelines provide principles of pollution control, and measures appropriate for commonly experienced situations in the ACT. The guidelines provide a comprehensive list of approaches for surface water management and sediment control. The guidelines are also called up in all development codes. This Investigation supports the recommendations in the *Water Sensitive Urban Design Review* (ACT Government 2014b) to strengthen the Guidelines with more information on how erosion and sediment control is staged. However, the issue has been to do with a lack of compliance.

The lack of compliance on development sites is not unique to the ACT. In NSW, the *Get the Site Right* campaign on sediment controls at building and construction sites found that about 50% of sites were complying in 2018. This Investigation therefore supports the Priority Project 7 (and the underlying recommendations 13.1, 13.2,13.3, 14.1, 14.2, 15.1 and 15.2) in the *Water Sensitive Urban Design Review report* which include working with the construction industry to improve their performance in erosion and sediment control during the building construction phase and investigating building certifiers to ensure compliance with site management requirements, including erosion and sediment control.

The 2017-18 annual report (ACT Government 2017a) for the *ACT and Regional Catchment Strategy* and Report Card for the *ACT Water Strategy* shows that engagement with builders and developers have begun, demonstration sites have been identified to showcase best practice erosion and sediment control methods, and a training video for construction workers on sediment and erosion control was in development. However, it is unclear from our review of the Implementation plan Two (ACT Government 2019a) of the *ACT Water Strategy* how the various elements of the Priority Project 7 and underlying recommendations are being addressed. It is worth taking the lessons learnt from the NSW *Get the Site Right* campaign (EPA NSW 2019a; EPA NSW 2020b) which has observed an increase in compliance following significantly heightened enforcement efforts by Council and EPA officers. In Victoria, a program undertaken by various Councils around 2005 consisting of engagement and education with builders, regulation and enforcement, and monitoring of compliance has also demonstrated improvement in compliance (Melbourne Water 2005). A suite of simple tools was also generated to support Council officers and builders, including communications package, on-site manual and audit checklist.

Key findings:

- Lack of compliance with erosion and sediment controls during land development is likely to be posing a significant threat to urban lakes, ponds and waterways.

Recommendations:

To increase compliance with erosion and sediment controls during construction, consideration should be given to a cross-agency arrangement between EPA, EPSDD, SLA to ensure a coordinated approach on:

- Awareness campaigns with estate developers and home builders to improve engagement with and understanding of construction impacts on waterways and how to reduce them
- Increasing capacity for undertaking compliance inspections, e.g., by SLA officers or by engaging building certifiers
- Greater enforcement of the sediment control obligations of builders, including financial penalties
- Regular audits to track progress on compliance performance, with penalties for non-compliance

5.2 Regulatory compliance and performance of WSUD assets in the private realm (block scale)

Under the ACT *Waterways WSUD General Code*, there is a requirement for a mains water use reduction target of 40% of pre-2003 levels, as well as stormwater detention and retention in all new developments and redevelopments. Solutions can be installed at a block scale such as water efficient fixtures and appliances and rainwater tanks. A by-product of meeting the mains water use reduction objective is a contribution towards stormwater pollutant load reduction. It is therefore important to ensure there is compliance with the code at the block scale so that the benefit to urban lakes and waterways is realised. Compliance is generally demonstrated through a report from a suitably qualified person consistent with the methods specified in the *ACT Practice Guidelines for Water Sensitive Urban Design*. Such methods can include use of the ACT water savings calculator.

However, issues with the quality of installation of rainwater tanks and ongoing performance have been observed in ACT. Anecdotal evidence suggests there are high incidences when rainwater tanks are installed without a connection to the house which means the 40% reduction target in mains use is unlikely to be achieved. A study undertaken across Melbourne by the CSIRO in 2015 found that 17% of existing household rainwater tanks were not actually plumbed in, and that 10% had non-functioning pumps and 8% had faulty electronic diverters (CSIRO, 2015). On the other hand, in NSW, the BASIX compliance audit report program report found that compliance was particularly high for rainwater tanks. The BASIX Water Savings Monitoring for 2010-11 report also indicated that BASIX dwellings are achieving close to the 40% reduction target.

Key findings:

- There is a likelihood of deficiencies in rainwater tank plumbing connection and in the quality of products including pumps and diverters.

Recommendations:

Consideration should be given to the following:

- An audit to understand levels of compliance in terms of rainwater tank plumbing connection and quality of products installed (including indoor fixtures and appliances, pumps and diverters)
- Making compliance part of the building or plumbing certification process such that all measures undertaken to meet the mains water use reduction target are certified by a suitable expert with the provision of a compliance certificate.
- Making it mandatory that the rainwater tanks are connected to new houses and townhouses.

5.3 Performance of WSUD assets in the public realm

In this section, we document key issues observed during construction, establishment and operation of Water Sensitive Urban Design infrastructure in the public realm. These are assets that are generally handed over to the ACT Government. The findings are based largely on information derived from previous Alluvium projects, including the findings of a 2015 audit of stormwater treatment assets in the ACT (Alluvium 2016; see also Appendix A), which included interviews with relevant ACT Government staff, asset inspections and asset performance monitoring. The findings remain valid and pertinent, despite more recent changes in policy and management.

5.3.1 Design phase

The Alluvium audit of the performance of stormwater treatment assets in the ACT in 2015 (Alluvium 2016) found that many fundamental issues were arising at the design stage including:

- Many systems lacked the fundamental features which are standard practice for effective stormwater treatment systems, including high flow bypass, extended detention and adequate pre-treatment.
- Inlets and diversion systems were consistently poorly designed so that in many cases, very little water is able to enter stormwater treatment systems.
- Maintenance was given inadequate consideration at the design stage, so there are issues regarding access; ponds and wetlands cannot be drained and bioretention systems lack flushing points.

The key reasons why these issues were occurring are outlined below, although it must be noted that there has been progress since the audit was completed in 2015.

- Limitations in capacity in the local industry; however, this has improved in recent years.
- Design Standards and Specifications are limited in their scope. The municipal infrastructure standards (ACT Government 2019d) have significantly closed the gap in standards available for a range of WSUD assets. However, they are based largely on design manuals developed in other jurisdictions.
- Poor vegetation selection has been one of the issues leading to vegetation failure in stormwater treatment systems.
- Within design teams for individual projects, there has sometimes been poor integration between civil, landscape and ecological design, with a lack of specialist expertise on stormwater treatment. In development projects, the civil consultant tends to have continuous involvement from the planning stage to implementation, but other design consultants have had more intermittent roles.
- Poor co-ordination between design teams working on separate but related projects – for example at Coombs, the regional ponds (Coombs Ponds A and B as well as Weston Pond) were designed and built ahead of the subdivision design and construction, and some of the design assumptions made for the pond design proved incorrect when the subdivision was constructed. Flow paths and catchment areas changed, and levels around the ponds changed, making it difficult to mesh the subdivision design with the regional infrastructure.
- In established urban areas, there is a need to re-think stormwater treatment beyond pond systems. A higher standard of treatment is now desired targeting finer and soluble pollutants (e.g., constructed wetlands, bioretention systems etc).

The ACT Healthy Waterways program has been an opportunity for the ACT Government to deliver a range of industry best practice stormwater treatment systems. Learnings from the delivery of these projects and ongoing management of the assets should be used to provide specific ACT context to design guidance and standards updates in the future.

By way of example, the *Canberra Urban Lakes and Ponds: Land Management Plan* describes how ACT lakes and ponds are designed for a pattern of progressive water quality improvement downstream as water moves through the lake or pond, resulting in three distinct water management zones. However, these zones, particularly Water Management Zone 1, have not been appropriately designed and constructed in almost all of Canberra's urban lakes and ponds, increasing the risk of poor water quality conditions and algal blooms in Zones 2 and 3.

Water Management Zone 1	Water Management Zone 2	Water Management Zone 3
(Inlet zone) is high in suspended solids, nutrients, organic material and bacteria. Typically, this zone comprises the shallow water–emergent aquatic plant ecosystems described above. It is a highly productive zone, sustaining high biomass of plants, macroinvertebrates, fish and birds. This zone is primarily managed for water quality processes and conservation purposes. The prevailing water quality conditions prevent body contact recreational activities. Intensive management of aquatic plants and rubbish in this zone is critical to sustaining the water quality and ecology of downstream zones.	(Intermediate zone) includes the edge of the macrophytes and clear water, with reduced (fine) levels of suspended material, nutrients and bacteria. It typically comprises extensive submerged macrophytes and epiphytic and planktonic algae. This submerged vegetation may limit boating activities. Prevailing water quality conditions may periodically prevent body contact recreational activities.	(Outlet zone) is low in suspended solids, nutrients and bacteria, and low in planktonic algae. Typically, this zone comprises the deep water–planktonic algal ecosystems described above. This zone can accommodate a wide range of water-based recreational activities on a reasonably frequent basis.

Recent observations on the current *Practice Guidelines for Water Sensitive Urban Design* are also made below. Design guidance and requirements are largely based on manuals developed in other jurisdictions. The Guidelines provide a comprehensive list of solutions and recommendations for development scale, type and site characteristics, however passive irrigation measures are not included in the list. They should be promoted as a solution as they support green infrastructure, which is an element of the *Waterways WSUD General Code* and *Canberra's Living Infrastructure Plan: Cooling the City* (ACT Government 2019e).

The guidelines include tools that can be used to demonstrate compliance with the code mains water use reduction, water quantity and water quality elements. However, more information is required on the tools available to demonstrate how green/living infrastructure criteria are met including how microclimate benefits are quantified, extreme temperatures are mitigated, and air humidity and human comfort are improved. The guidelines can refer to the guide for microclimate assessment (when released) which is an action in the Living Infrastructure Plan.

Key findings:

- Limited capacity in industry means WSUD assets are poorly designed and fail to provide level of service required once constructed.
- Poor integration of disciplines means stormwater, landscape and ecological outcomes suffer.
- Poor coordination between design teams working on subdivision design and regional WSUD infrastructure resulting in sub-optimal outcomes for stormwater treatment
- There is a need for existing urban lakes and ponds to be redesigned and retrofitted with appropriate structures to meet the water management zone requirements of the *Draft Canberra Urban Lakes and Ponds Land Management Plan*.

Recommendations:

Consideration should be given to the following:

- An audit of recently completed projects to determine if the quality of WSUD asset design has improved, and to obtain feedback on the application of the *Municipal Infrastructure Standards 08* (ACT Government 2019d).
- Contracts that encourage an integrated approach from developers and their consultants, supported by multi-disciplinary teams within ACT government (e.g., covering urban planning, urban and landscape design, bushland and waterway management, engineering, WSUD on project teams).
- Establishing a process that ensures coordination of regional WSUD infrastructure and land use planning in catchments and that infrastructure is planned and designed in line with stormwater management objectives for the catchment. This should include consultation with the proposed integrated catchment management entity (see Section 3.1).
- Consideration should be given to establishing a program to rectify Canberra urban lakes and ponds to delineate water management zones more effectively and achieve water management zone objectives

described under the *Draft Canberra Urban Lakes and Ponds Land Management Plan*. This can build on rectification projects proposed under the 2015 ACT Basin Priority Project.

5.3.2 Construction phase

The Alluvium audit of the performance of stormwater treatment assets in the ACT in 2015 (Alluvium 2016), found the most significant construction-related issue in new developments was around staging, with stormwater treatment infrastructure being constructed and established relatively early in the construction phase while there was still significant amounts of sediment moving off the landscape into drainage lines and creeks. Vegetated stormwater treatment systems such as wetlands, bioretention systems and swales are not designed to capture construction sediment and are easily over-loaded with sediment during the construction phase, causing significant damage which is not easily rectified. Many GPTs can also be damaged by construction-stage sediment loads.

Ponds are appropriate for capturing construction sediment. However, there is a significant difference between a simple construction-stage sediment pond, which is designed as a short-term installation to capture a large sediment load (interim stage), and a pond or wetland designed for long-term water quality management as well as broader landscape, community and ecological objectives.

Based on interviews with key stakeholders and review of specific assets as part of the Alluvium audit of the performance of stormwater treatment assets in the ACT in 2015 (Alluvium 2016), we observed that:

- Vegetated stormwater treatment systems were not appropriate to receive sediment loads during the estate development stage even with best practice erosion and sediment control measures in place during that stage.
- During the house-building stage, erosion and sediment controls were poorly implemented.
- There were also other impacts at the construction stage (both estate and house-building stages) that damage vegetated stormwater treatment systems, particularly where they were located in the streetscape or otherwise close to other works. For example, vehicle movements, construction debris and general litter were all significant issues.
- Vegetated stormwater treatment systems were routinely completed too early in the development process and subsequently damaged by construction sediment loads. Examples included the ponds at Coombs, the bioretention basin and some of the streetscape rain gardens at Crace, and the swale at Plimsoll Drive.

Figure 16. *Construction sediment control issues at Coombs (Source: ACT Government)*

It is noted that a number of the options are now provided in the *ACT Practice Guidelines for Water Sensitive Urban Design* (ACT Government 2018b) to prevent damage to WSUD assets from sediment during construction. It is beyond the scope of this project to obtain feedback on the application and effectiveness of these options since the release of the guidelines document.

5.3.3 Establishment phase

Establishment is a key stage in the life cycle of a vegetated stormwater treatment system, but it is a stage that in the past has had insufficient attention in the ACT. Key issues have included:

- In some of the wetlands and ponds (including Emu Bank wetland, Coombs Ponds A and B) investigated there was evidence that wetland vegetation was drowned in deep water before it was sufficiently established. Wetland plants establish well in shallow water and water level increases needs be managed during establishment so that part of the plant always remains above the water level.
- Mabo Boulevard provided a striking example where good establishment in the upper sections of the swale has led to better outcomes since asset handover – vegetation remains in reasonable condition. However poor establishment in the lower sections of the swale led to significant deterioration post-handover.
- Plimsoll Drive had significant establishment issues – the developer attempted to establish the swale online while there was significant construction activity still underway in the catchment.

The causes behind establishment issues are generally that:

- Establishment is a less critical issue for other types of public assets and therefore government systems are generally not set up to deal with a long establishment phase.
- Establishment of wetland vegetation in particular is a specialist skill which is not widely understood in the industry.
- Along with maintenance, establishment is given inadequate consideration at the design stage. For example, there is sometimes no provision to take systems offline, drain permanent water or manually control water levels during plant establishment.
- Construction contracts do not typically include a meaningful allowance for plant establishment.
- Construction timelines often encourage early handover before establishment is complete.
- The establishment phase is maintenance intensive and unless it is clearly identified as part of the implementation cost (e.g., as part of a specific contract), it may be difficult to resource.

However, despite these challenges, effective establishment does pay off in the long run due to reduced maintenance costs over the life of an asset.

It is noted that guidance on establishment is now included in the *ACT Practice Guidelines for Water Sensitive Urban Design* (ACT Government 2018b). It is beyond the scope of this investigation to understand exactly how much improvement there has been in the establishment of WSUD assets since the release of the guidelines document.

5.3.4 Operations and maintenance phase

A key issue associated with many treatment systems is that after systems are installed, the ACT Government is under-resourced for the operations and maintenance stage and unable to maintain treatment systems in working order and deliver the level of service required. This means treatment systems are not maintained regularly enough and some receive no maintenance at all. Therefore, the benefit to the urban lakes, ponds and waterways is not realised over the long term.

The number of stormwater treatment systems has increased rapidly in the ACT over the past decade, and the maintenance budget has not kept up with this increase. This is an issue that is relatively common in jurisdictions until a business case is raised to ensure that an appropriate maintenance approach is adopted.

- In ponds, lakes and wetlands there is no routine maintenance undertaken within the water body itself. These systems are only desilted occasionally when sediment builds up to a level which demands action. However well before sediment reaches this level, many ponds and lakes appear to have water quality issues associated with re-release of pollutants from material building up within the water body. Most wetlands have very poor macrophyte health and are therefore performing well below their expected level of service.
- In some areas, the capacity to maintain bioretention systems/rain gardens is so limited that they are not being maintained at all, and many of these systems are not working. Bioretention systems are low maintenance, but prone to failure if not maintained at all.
- Gross pollutant traps are generally cleaned out twice per year, which is a relatively low frequency, and means that organic matter accumulating in GPTs decomposes anaerobically between cleanouts, causing re-release of pollutants.

The Alluvium audit of the performance of stormwater treatment assets in the ACT in 2015 (Alluvium 2016), found the operations and maintenance budget is so limited that staff describe their job as entirely reactionary. Asset management systems are inadequate, and maintenance plans and life cycle costing information is not being captured in current processes. There is little opportunity for operations and maintenance staff to feed useful information back to the rest of government or industry. In this context, we expect that there is also very little capacity for investment in staff training or equipment to maintain new types of stormwater treatment assets such as bioretention systems. It is not clear or apparent that these issues have been resolved since the 2016 review.

The *Waterways WSUD code* now requires provision of an operations and maintenance plan for WSUD assets at the design stage. However, the lack of funding for WSUD asset operation and maintenance means the level of service is not maintained on an ongoing basis which has implications for the health of the Murrumbidgee River and urban lakes and waterways in the ACT.

Key findings for the construction, establishment and operations and maintenance stages:
The following issues arise in these stages that affect level of service that the WSUD assets provide in the long-term including:

- Excessive sediment loads into, and damage to, WSUD assets at the home construction stage
- Little attention to the establishment of vegetated stormwater treatment system
- ACT Government is under-resourced for the operation and maintenance of WSUD assets.

Recommendations:
Consideration should be given to the following:

- Continuing or re-investing in the implementation of all 8 priority projects and the list of recommendations identified in the *Water Sensitive Urban Design Review* report (ACT Government 2014b) as part of current or future *ACT Water Strategy* implementation plans.
- An audit of recently completed projects (including interviews) to obtain feedback on the application and effectiveness of options to avoid damage to stormwater treatment systems from sediment during construction as provided in the *ACT Practice Guidelines for Water Sensitive Urban Design* (released in 2018).
- An audit of assets currently under establishment or recently completed (including interviews) to obtain feedback on the application and effectiveness of guidance on establishment of WSUD assets as provided in the *ACT Practice Guidelines for Water Sensitive Urban Design* (released in 2018).

6 Opportunities for improved governance arrangements

As discussed in section 3, ACT Government policies and strategies do not adequately address integrated catchment management at an urban scale. There is currently no clear governance structure to guide strategic decision-making for protecting and improving the health of urban lakes and waterways in the ACT. An entity or agency that is responsible and accountable for integrated catchment management at an urban scale and for making strategic decisions for the urban lakes, ponds and waterways, including stormwater management in the ACT, is needed, or these responsibilities and accountabilities need to be explicitly assigned to an existing group or agency.

The entity should aim to develop a catchment management strategy for urban areas through collaboration with key stakeholders and based on understanding of processes and interactions at the local and broader catchment scale. It should also have the capacity to operationalise and implement the strategy. The proposed entity should align its activities, within an urban context, to the actions under outcome 1 of the *ACT Water Strategy* – Healthy catchments and waterbodies: Well-managed, functioning aquatic ecosystems that protect ecological values and contribute to the liveability of the ACT community. The catchment management strategy should guide application of the *WSUD Code,* including how “development targets” and “regional targets” for stormwater treatment will be applied to meet the *ACT Water Strategy*.

An important element will be to develop a shared vision for the urban lakes, ponds and waterways and to recognise the multiple roles that they perform including water quality management, as well as the range of environmental, social and economic values that they provide. The *Canberra Urban Lakes and Ponds: Land Management Plan* describes the management objectives of Canberra’s urban lakes and ponds. These are to:

1. Prevent and control floods by providing a reservoir to receive flows from rivers, creeks and urban run-off.
2. Prevent and control pollution of waterways.
3. Provide for public use of the lake or pond for recreation.
4. Provide habitat for fauna and flora.

However, these objectives are not necessarily aligned or complementary, and all of these objectives are applied to all urban lakes and ponds in the ACT, so the primary objective (or objectives) of each individual water body is unclear.

In addition, in accordance with section 317 of the *Planning and Development Act 2007*, if there is an inconsistency between the application of two management objectives, the objective appearing later in the schedule is to be read subject to the earlier objective, thus creating a hierarchy of management objectives. As such, a lake may be managed to control floods and mitigate the pollution of downstream waterways ahead of any public use or ecological objectives. Problems with community expectations and satisfaction are exacerbated if the primary objective(s) of each waterbody is not clearly stated and understood.

The objectives and desired outcomes associated with urban lakes, ponds and waterways should be the context for assessing the costs and benefits of any waterway investment decisions and prioritising effort and investment. Sub-catchment strategies should also be developed for each key lake, pond and waterway, with specific visions, goals and placed-based objectives, action plans and targets (including water quality, flow, ecological and biophysical targets) in the short, medium and long-term covering both existing and greenfield urban areas.

Facilitating legislation would be required to provide sufficient authority for the effective undertaking of this role. This role should specifically include working collaboratively with other agencies within the ACT Government, ICON water, National Capital Authority, NSW Government and local governments in NSW within the catchments relevant to the ACT. It should also collaborate with entities/agencies responsible for implementing the *ACT Living Infrastructure Plan* and for developing/implementing the “holistic water cycle management plan” which is scheduled to be developed 2020-21 as per the Implementation Plan Two (ACT Government 2019a) of the *ACT Water Strategy*. This entity should work with the ACT and Region Catchment Management Coordination Group (CMCG) where cross-jurisdictional matters are concerned e.g., for management of Lake Burley Griffin.

Whilst the proposed entity will provide a technocratic “top-down” approach to catchment planning and management, it is also critical in the ACT that consideration is given to a “bottom-up” approach where diverse forms of knowledge and the community are involved in deliberative decision making. This is because there is significant community interest in the management of water and land resources in urban areas (e.g., Waterwatch, Landcare, Catchment Groups). Many ponds and lakes are viewed by the community as important community assets. The ACT government has already begun to explore using deliberative democracy for environmental issues and continuing this was recommended in the most recent ACT State of the Environment report (CSE 2019, recommendation 8). Deliberative decision making has been emerging as an aspect of best practice to improve stormwater management in Sydney (Brown, Ryan & Ball 2004). The Marrickville Council Waterevolution is a recent case study of an urban area in Sydney using this approach to move towards being a Water Sensitive City (Marrickville Council 2012; 2014). The new approach addresses three identified problems in conventional urban water management:

- Technical experts, particularly engineers, have traditionally been responsible for developing solutions to complex urban water problems. It is now recognised that we need to take a more holistic approach and include other thinkers, such as social scientists and ecologists.

  Solution: Integrate the many disciplines, e.g., sociology, ecology, urban planning and engineering.

- The people affected by urban water problems, including residents, businesses, community groups and government departments have usually not been involved enough in planning discussions.

  Solution: Involve the community of interest in the decision making and implementation.

- In the past, plans have been designed for whole river catchments rather than one appropriate and practical ‘locally grown’ solution to urban water problems.

  Solution: Reduce the planning unit to the local level, e.g., sub-catchments

7 Consolidated recommendations

All recommendations arising from this review are consolidated in the table below, along with suggested broad timeframes for their implementation.

Issues	Recommendations	Timeframe*
Urban catchment and waterway management and governance		
ACT Government policies and strategies do not address integrated catchment management at an urban scale. There is currently no governance structure to guide strategic decision making for protecting and improving the health of urban lakes and waterways in the ACT.	Consideration should be given to: • Establishing an entity that is responsible and accountable for integrated catchment management at the urban and peri-urban scale and for making strategic decisions for the urban lakes, ponds and waterways including stormwater management in the ACT. • Developing a long-term funding strategy to support the activities of the proposed entity based on revenue collected from the ACT Water Abstraction Charge (WAC). • Aligning the activities of the proposed entity to the 10 actions under the "ACT Water Strategy Outcome 1 – Healthy catchments and waterbodies".	Short term
As outlined in the Auditor-General's Report on Acceptance of Stormwater Assets (2018), an agency-focused negotiation process currently determines what design is to be used and consequently what asset is accepted. This process is not necessarily tied to catchment management objectives and environmental outcomes	Consideration should be given to establishing a process that ensures coordination of regional WSUD infrastructure and land use planning in catchments, and that infrastructure is planned and designed in line with stormwater management objectives for the catchment. This should include consultation with the proposed integrated catchment management entity (see Section 3.1).	Medium term
Agency and stakeholder coordination		
It is possible that consultation during the development application and design review stages does not cover all the required entities in the ACT Government (or teams within the relevant entities). This means that possible issues for instance with maintenance are not picked up early in the process.	Consideration should be given to: • Developing a stakeholder consultation plan to ensure the right stakeholders are consulted at each stage of the WSUD asset life cycle, including in repeat cycles. The consultation process should begin in the strategic planning phase with early establishment of operation and maintenance requirements. • Occasional external audits to assess processes at each stage of the WSUD life cycle including development approval, asset design approval and asset acceptance processes.	Short term and ongoing
Poor integration of disciplines means stormwater, landscape	Consideration should be given to having contracts that encourage an integrated approach from developers and their consultants, supported by multi-disciplinary teams within	Medium term

Issues	Recommendations	Timeframe*
and ecological outcomes suffer.	ACT government (e.g., covering urban planning, urban and landscape design, bushland and waterway management, engineering, WSUD on project teams).	
Communication of the key roles and objectives of each urban lake and pond		
There is a need for policy and governance to recognise the multiple roles that lakes and ponds perform and fully understand the range of environmental, social and economic values that they provide. The *Water Use and Catchment General Code* does not articulate environmental and community values of urban lakes, ponds and waterways including requirements for water quality and flows. There is poor linkage of this code with the *Waterways WSUD Code*.	Consideration should be given to: • Reviewing the *Water Use and Catchment General Code* to reflect environmental and community values of urban lakes, ponds and waterways including requirements for water quality and flows. • Better linkage between the *Water Use and Catchment General Code*, the *Waterway WSUD Code* and the *Canberra Urban Lakes and Ponds: Land Management Plan.*	Short-term
Flow and water quality objectives for urban lakes, ponds and waterways in urban catchments are not well defined for social and environmental values. Stormwater quality targets and stormwater retention targets in the *Waterways WSUD code* are not tied to environmental outcomes in the receiving waters.	Consideration should be given to developing flow and water quality objectives for urban lakes, ponds and waterways. The objectives should build on previous scientific studies, the *Environmental Flow Guidelines,* and the *Canberra Urban Lakes and Ponds: Land Management Plan*. Where knowledge gaps on environmental values exist, detailed field assessment should be undertaken to improve the state of knowledge (in addition to the data collected by Waterwatch).	Short to medium term
Improving WSUD practice in the ACT		
Limited capacity in industry means WSUD assets are poorly designed and fail to provide level of service required once constructed.	Consideration should be given to an audit of recently completed projects to determine if the quality of WSUD asset design has improved, and to obtain feedback on the application of the municipal infrastructure design standards (released in 2019).	Short term
Sometimes, a lack of capacity in Government in WSUD hinders the ability of staff to undertake meaningful review at development application and design review stages.	ACT Government to continue to build its capacity in WSUD asset delivery	Ongoing

Issues	Recommendations	Timeframe*
The practice of WSUD in the ACT broadly, and the legislative instrument (*Waterways: WSUD General Code*) specifically, needs to improve to enhance outcomes for urban lakes and waterways	Consideration should be given to: • Continuing or re-investing in the implementation of all 8 priority projects and the list of recommendations identified in the *Water Sensitive Urban Design Review* report (ACT Government 2014b) as part of current or future *ACT Water Strategy* implementation plans. • Increasing the rule for site permeability from a minimum of 20% to a minimum of 30% under the green/living infrastructure element in order to align with the *Living Infrastructure Plan*'s target of 30% permeable surfaces in Canberra's urban footprint by 2045. • Increasing the mains water use reduction target from 40% to 50% of pre-2003 levels in all new developments and redevelopments. This is due to improvements in recent years in the efficiency ratings of household plumbing fixtures and appliances, the potential for inclusion of flow restrictors on outdoor plumbing fixtures, and the potential to increase roof water collection area requirements. • Defining the term "reuse" in the stormwater retention objective so that combination of indoor end uses, infiltration, evaporation and evapotranspiration measures are acceptable. • Amending the *Waterways: WSUD General Code* to require stormwater quality treatment in all catchments within which urban development is planned, irrespective of whether water quality targets have been met. • Amending the *Waterways: WSUD General Code* to require scenario modelling and mitigation measures that ensure any development results in an EPI of unity.	Short term
Areas for improvement in the WSUD practice guidelines (and Design Standards)	Consideration should be given to the following inclusions in the next version of the Guidelines and Design Standards: • Learnings from the delivery and management of stormwater treatment infrastructure as part of the *ACT Healthy Waterways* Project and industry projects (e.g., greenfield development) to provide more ACT context to the guidelines, including details on the re-design, rectification and renewal of existing assets. • Novel solutions such as passive irrigation measures that can be used meet the stormwater retention and green/living infrastructure element of the Code. • Tools that can be used to demonstrate how green/living infrastructure criteria are met including how microclimate benefits are quantified, extreme temperatures are mitigated, and air humidity and human comfort are improved. • Updates to align with recommendations from the ACT *Living Infrastructure Plan* and the "holistic water cycle	Short to medium term

Issues	Recommendations	Timeframe*
	management plan" which is scheduled to be developed 2020-21 as per the Implementation Plan Two of the *ACT Water Strategy*.	
There is a need for existing urban lakes and ponds to be redesigned and retrofitted with appropriate structures to meet the water management zone requirements of the *Draft Canberra Urban Lakes and Ponds Land Management Plan*.	Consideration should be given to establishing a program to rectify Canberra urban lakes and ponds to delineate water management zones more effectively and achieve water management zone objectives as described under the *Draft Canberra Urban Lakes and Ponds Land Management Plan*. This can build on rectification projects proposed under the 2015 ACT Basin Priority Project	Medium term
Monitoring		
There is a need for more coordinated approach to monitoring environmental values, flows and water quality in urban lakes, ponds and lakes. The ACT Government is relying heaving on community-based volunteer efforts such as Waterwatch for this monitoring.	Consideration should be given to: • prioritising Action 4 of the *ACT Water Strategy* – Improve water monitoring and analysis across the ACT and region – in urban catchments including: o better integration of Waterwatch and AUSRIVAS activities o identifying priority gaps in monitoring and undertake additional monitoring to understand the impact of extant and future urban catchments o monitoring performance of existing WSUD, including ponds and wetlands, with the aim of improving design guidelines for future infrastructure. • prioritising the following, adapted from Implementation Plan Two of *The ACT Water Strategy*: o the identification of monitoring gaps in urban catchments o additional water quality and flow monitoring in urban lakes, ponds and waterways o assessment of water treatment performance of WSUD assets such as constructed wetlands, including monitoring of the receiving waters of treatment trains o improved access to monitoring data, including collected as part of the Integrated Water Quality Monitoring Program.	Short to medium term
Urban waterways riparian and aquatic strategy		
There is no clear strategy for protecting and enhancing aquatic and riparian health of urban lakes and waterways.	Consideration should be given to: • Developing an urban aquatic and riparian strategy as part of the urban catchment management strategy to protect and enhance the condition of aquatic and	Medium term

Issues	Recommendations	Timeframe*
Land development is having a direct impact on the aquatic and riparian health including in the Molonglo and Murrumbidgee Rivers. This is arising from poor erosion and sediment control practices during construction, and limited guidance (and lack of application of existing guidance) on design of stormwater discharges at the urban edges.	riparian environments in existing urban and urbanising areas. Guidance from the non-urban ACT Aquatic and Riparian Conservation Strategy could be used to inform an urban aquatic and riparian strategy with a view to improving water quality from urban areas. • Developing an urban buffer Land Use Zone adjacent to the Molonglo and Murrumbidgee River corridor zones that allows sufficient space to mitigate high stormwater flows that avoids any requirement for engineered structures within the river corridor reserves themselves. • Developing a program to rehabilitate urban waterways including: o Naturalisation of concrete channels in the lower reaches o Naturalisation of concrete swale and grassy banks in the mid reaches o Rehabilitation of disturbed reaches in the upper catchment where greenfield developments are proposed.	
Regulation and compliance		
Lack of compliance with erosion and sediment controls during construction	Consideration should be given to a cross-agency arrangement between EPA, EPSDD, SLA to ensure a coordinated approach on: • Awareness campaigns with estate developers and home builders to improve engagement with and understanding of construction impacts on waterways and how to reduce them • Increasing capacity for undertaking compliance inspections, e.g., by SLA officers or by engaging building certifiers • Greater enforcement of the sediment control obligations of builders, including financial penalties • Regular audits to track progress on compliance performance, with penalties for non-compliance	Medium term
There is a likelihood of deficiencies in rainwater tank plumbing connection and in the quality of products including pumps and diverters	Consideration should be given to: • An audit to understand levels of compliance in terms of rainwater tank plumbing connection and quality of products installed (including indoor fixtures and appliances, pumps and diverters) • Making compliance part of the building or plumbing certification process such that all measures undertaken to meet the mains water use reduction target are certified by a suitable expert with the provision of a compliance certificate.	Medium term

<table>
<tr><th>Issues</th><th>Recommendations</th><th>Timeframe*</th></tr>
<tr><td></td><td>Making it mandatory that the rainwater tanks are connected to new houses and townhouses</td><td></td></tr>
<tr><td>Issues arise at construction, establishment, and operations and maintenance stages of WSUD assets that affect the level of service that they provide in the long-term including:
Excessive sediment loads and damage to WSUD assets at the home construction stage
Little attention to the establishment of vegetated stormwater treatment system
ACT Government is under-resourced for the operation and maintenance of WSUD assets in working order</td><td>Consideration should be given to:
An audit of recently completed projects (including interviews) to obtain feedback on the application and effectiveness of options to avoid damage to stormwater treatment systems from sediment during construction as provided in the ACT Practice Guidelines for Water Sensitive Urban Design (released in 2018).
An audit of assets currently under establishment or recently completed (including interviews) to obtain feedback on the application and effectiveness of guidance on establishment of WSUD assets as provided in the ACT Practice Guidelines for Water Sensitive Urban Design (released in 2018).</td><td>Medium term</td></tr>
<tr><td colspan="3">Cost effectiveness and benefit analyses</td></tr>
<tr><td>Some assets constructed under the ACT Healthy Waterways program were found to be less cost effective in terms of pollution abatement compared to average of estimates in other jurisdictions.

Valuation of benefits other than pollution abatement e.g., biodiversity improvement, urban cooling and recreation are heavily assumption-driven in absence of primary study.

The benefits from the expected behaviour change were starkly low. Although attributable to conservative assumptions for behaviour change, it also identifies the potential for behaviour change initiatives to improve the overall benefit from similar programs in the future.</td><td>Consideration should be given to:
Cost-effectiveness analysis for WSUD investments prior to allocation of funds to improve decision-making in selection of projects and sites and in maximising total potential benefits from program planning. Assessment of project risks should consider impact on cost-effectiveness should certain risks eventuate.
Cost-benefit analysis in conjunction with a cost-effectiveness analysis to give transparent metrics for funding allocation and enhance communication of decision-making with stakeholders.
Undertaking primary studies to better understand the range of ecosystem service benefits derived from WSUD investments such as biodiversity improvement, urban cooling and recreation. This will improve assumptions used in cost-benefit analyses.
Education initiatives for similar programs in the future to improve behaviour changes. The benefit of lasting behaviour changes is that it can reduce the need for large WSUD asset investments in the long term.</td><td>Ongoing</td></tr>
</table>

* Short term: 1-2 years,   Medium term: 3-5 years

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Appendix A – 2015 Review of stormwater treatment assets in the ACT

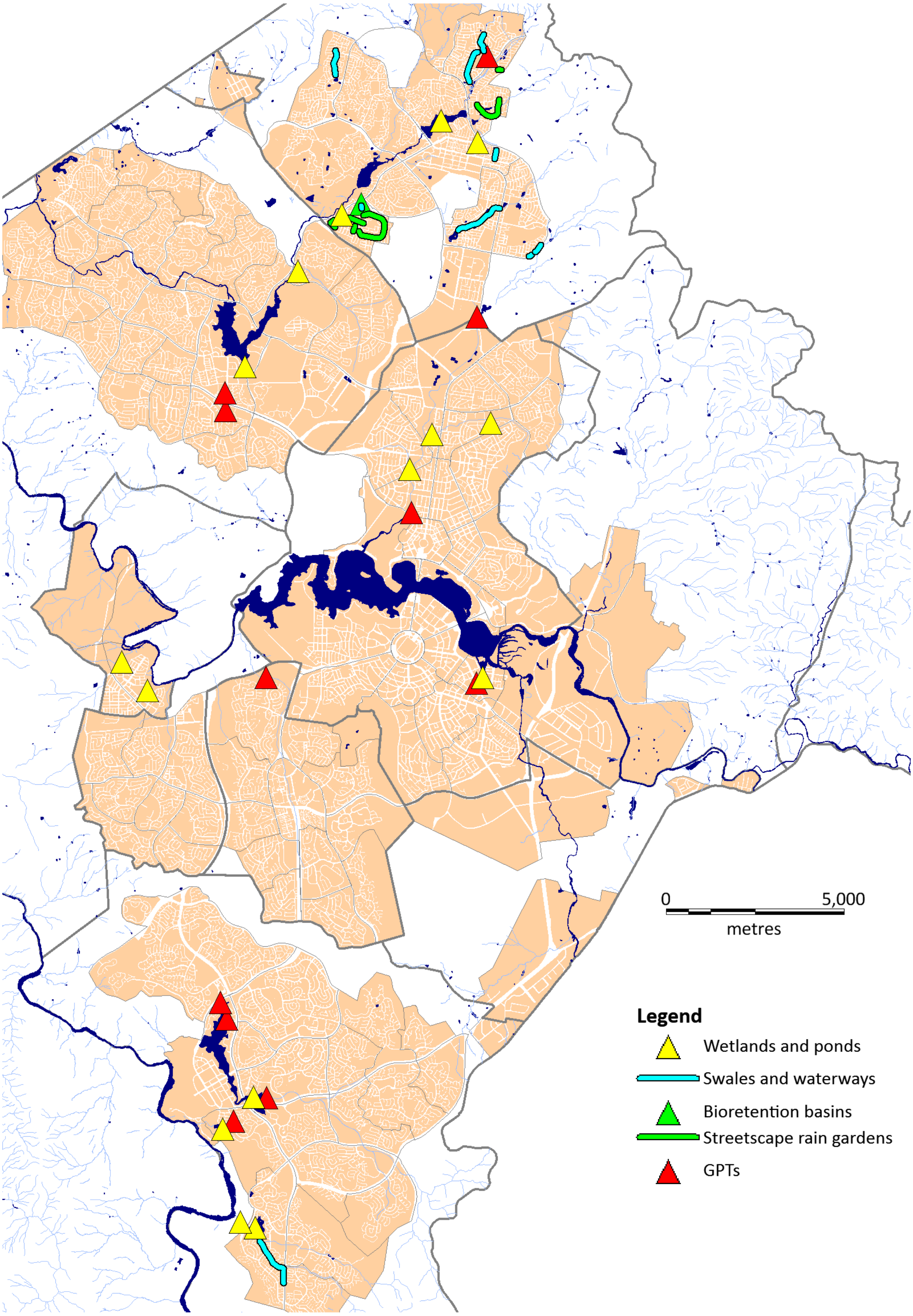

Figure 17. *Overview of asset locations*

Large ponds and lakes

Large ponds and lakes are a feature of Canberra's stormwater management systems and a distinguishing characteristic of urban development in the ACT. The *Canberra Urban Lakes and Ponds: Land Management Plan* (ACT Government 2019c) identifies a vision for the lakes and ponds:

> *"To enrich local communities through the aesthetic, recreational, sport, tourism and ecological values of lakes and ponds, and to provide opportunities for people to be involved in their use, care and management"*

Therefore, while most of these systems are identified at some level as water quality treatment systems, they have multiple objectives and their stormwater treatment role is not necessarily the role most valued by the community.

We have categorised the water bodies in this review into two categories, chiefly based on their size. The large ponds and lakes:

- have a surface area in excess of 1 ha
- are predominantly open water
- are generally deeper than 1.5 m
- are typically located online
- have broader objectives beyond water quality treatment
- are regional infrastructure which serves more than a single development/estate or suburb
- have therefore been delivered by the ACT government rather than land developers.

The large ponds and lakes reviewed in this project are listed in *Table 3*. Even amongst these larger systems, there is a significant range of scales from 1.2-25.9 ha.

Table 3: Large ponds and lakes reviewed

Name	Surface area (ha)
Dickson pond	1.2
Lyneham pond	1.5
Giralang pond	1.3
Point Hut Pond	15.5
Coombs Pond A	1.8
Coombs Pond B	4.5
Yerrabi Pond	25.9
Isabella Pond	6.8
Lower Stranger Pond	4.1

Appropriateness

In the 1980s and 1990s, large ponds and lakes were commonly used as a stormwater treatment measure. In 1998, the CRC for Freshwater Ecology published the "Design Guidelines: Stormwater pollution control ponds and wetlands" (Lawrence and Breen 1998), which represented best practice in stormwater treatment at that time. While these guidelines provide advice about a wide range of pond and wetland design configurations, there is an emphasis in the design advice on large online ponds. The ACT's Design Standards for Urban Infrastructure – DS 16: Urban Wetlands Lakes and Ponds (Urban Services, undated) also focuses on large, online ponds with minimal macrophyte zones around their edges. Extended detention and offline systems are noted as "emerging issues" in the final section of this document.

Point Hut Pond, Yerrabi Pond, Isabella and Lower Stranger Ponds were all constructed in the 1980s and 1990s. In the ACT the use of ponds has continued to the present day, with the Dickson, Lyneham and Coombs Ponds only recently constructed. Giralang Pond is thought to be older with a construction date in the 1970s.

Large ponds and lakes are effective for sedimentation of particulate matter, including fine suspended solids and adsorbed pollutants. However, they are most effective when:

- they are sized appropriately for the catchment
- primary treatment is provided upstream to manage litter and debris as well as coarse suspended solids
- they provide “plug flow” conditions – steady, well-distributed flow
- they are shallow enough to be protected from temperature stratification.

Objectives

Large ponds and lakes have been designed in the ACT for stormwater treatment purposes but also have important roles to play in:

- attenuating peak flows
- recreation, including fishing, boating, passive recreation
- landscape outcomes such as microclimate and amenity
- water storage
- habitat
- community engagement.

It is not known whether the older ponds (Point Hut Pond, Yerrabi Pond, Isabella and Lower Stranger Ponds) were designed to meet any specific water quality targets. At Coombs, Ponds A and B were designed to meet the “regional” pollutant load removal targets set in the ACT WSUD Code (additional suspended solids, phosphorus and nitrogen removal over the development targets). At Dickson and Lyneham, we understand that the design of the ponds was driven more by flow attenuation and water supply objectives rather than as water quality treatment systems, however the design reports include ambitious estimates of expected suspended solids, phosphorus and nitrogen removal.

What performance issues are occurring?

There is no event-based stormwater quality monitoring data available for large ponds and lakes, so it is impossible to fully assess their performance as stormwater quality treatment systems. More information is available on the in-pond water quality issues.

Urban ponds and lakes commonly display long-term management issues including poor in-pond water quality, algal blooms and weed outbreaks. Low dissolved oxygen, high nutrient concentrations and high chlorophyll-a are common issues. As organic matter accumulates and breaks down in a pond, dissolved oxygen levels drop and decomposition is anaerobic. Under these conditions, many pollutants normally adsorbed to suspended solids, including phosphorus, are re-released into the water column. Odours are common, algal blooms can be triggered as a result and in extreme cases, the low DO levels can cause fish kills. Temperature stratification exacerbates the issue by discouraging oxygen transfer from shallow to deep water. A long-term build-up of accumulated pollutants can also exacerbate the issue.

Many jurisdictions in Australia have therefore moved away from large ponds and lakes as stormwater treatment systems. The ACT has continued to build them, however many of the ACT’s ponds, particularly the older ponds, are suffering from long-term water quality issues exactly as described above.

Another prevalent issue in the ACT’s ponds and lakes is an excessive build-up of sediment. In some cases (for example this is occurring at Coombs right now), this has occurred during urban development in the catchment. None of the large ponds and lakes are designed to be regularly drained (while some have dam valves, they are only intended to be drained in an emergency) and this means that sediment removal is a difficult and costly process.

Note that maintenance activities at the large ponds and lakes are minimal. Civil maintenance is largely confined to management of any GPTs at inlets and the dam and outlet structure, while landscape maintenance is confined to mowing and weed spraying around the pond edges. Neither the civil nor landscape maintenance teams have clear responsibility for maintaining the water body itself. The landscape maintenance team raised a concern that new ponds are being constructed with excessive maintenance requirements (e.g., Lyneham Pond), however it appears that they are primarily concerned with the maintenance of "shrub beds" around the terrestrial edges of the system, rather than maintenance of the pond itself. Landscaped shrub beds are not an essential feature for water quality treatment, and there are examples in the ACT (e.g., Lower Stranger Pond) where informal low-maintenance landscaping includes a variety of trees, shrubs, sedges and grasses and an attractive landscape outcome.

Why are these performance issues occurring?

Many of the performance issues noted above are typical of urban ponds and simply a feature of this type of infrastructure. However, performance issues in ponds are exacerbated by the following factors:

- High sediment loading during the construction stage. Inappropriate development staging and poor erosion and sediment controls contribute to this problem.
- High organic matter loads (including leaf litter and grass clippings). Organic matter loads tend to be high in the ACT due to the prevalence of large trees and large areas of mown grass in the public and private domain.
- Undersized ponds. Undersized ponds are easily overloaded with suspended solids and organic matter. High BOD (biochemical oxygen demand) loading exacerbates in-pond water quality issues – for example Giralang Pond is significantly undersized for its catchment and has significant water quality issues.
- Minimal pre-treatment upstream. Many of the ACT's ponds have minimal upstream pre-treatment. This is particularly true of the ponds in Tuggeranong, where flows are conveyed in concrete channels, and typically the only pre-treatment upstream of a pond is a gross pollutant trap. Gross pollutant traps are discussed further below.
- Pond maintenance. In the ACT, desilting of ponds is not planned for at the design stage, is not undertaken as part of routine maintenance, is not budgeted for and is generally only undertaken on a reactionary basis when necessary and when funds allow. Because large ponds and lakes are not designed with sediment removal in mind, this tends to be a difficult and costly exercise. Suspended solids and organic matter have therefore probably accumulated to a significant degree in many ponds, and are probably contributing to in-pond water quality issues associated with anaerobic decomposition.
- Pond location and design. Many of the large ponds and lakes in the ACT are relatively deep and prone to stratification, which exacerbates in-pond water quality issues.

Opportunities to improve performance

Despite the water quality issues identified above, in general the ACT's large ponds and lakes have proved relatively robust and able to cope with low maintenance. There is the risk, however, that water quality issues increase over time as catchments become increasingly urbanised and accumulated pollutants continue to build up in these systems.

A wide range of options exists for addressing performance issues in the large ponds and lakes:

- Most of the large ponds and lakes could be **maintained** as they are. With the possible exception of Giralang Pond, most of the large ponds and lakes are not suffering from urgent problems.
- In some cases, a simple **renewal** of the existing asset to clean out accumulated sediment and decomposing organic matter could assist in improving in-pond water quality. This is particularly true of the older ponds – Giralang Pond, Point Hut Pond, Yerrabi Pond, Isabella and Lower Stranger Ponds.

Before this is undertaken, we would recommend further investigation into the quality and quantity of accumulated material to understand its role in pond water quality and the potential implications of removal. TAMS advised that they monitor sediment accumulation in ponds to identify when sediment removal is required. TAMS suggested that the large ponds and lakes are generally filling with sediment at a slow rate, however we would like to review this information to better assess this issue.

- In some cases, minor **rectification** works could resolve site-specific issues (e.g., replacement of the GPT at Lyneham Pond, improvement of the diversion structure at Dickson Pond, repair of edge erosion at Lower Stranger Pond) with some bearing on the water quality performance.
- Most of the ponds could be **redesigned** to some extent to improve their function as water quality treatment systems. This could range from simple to complex measures, for example:
    - Dickson and Lyneham ponds already have extended detention and a riser outlet which is designed for a reasonable detention time within the pond. This arrangement could be retrofit to other sites and would introduce more water level variation to the system. This is potentially feasible at any of the large ponds and lakes.
    - In conjunction with the above, more macrophyte plantings could be established around the edges, in the shallow and ephemeral zones.
    - Some of the smaller systems could potentially be completely redesigned to incorporate features such as an extensive macrophyte zone, separate sediment basin and high-flow bypass. This is not likely to be practical at the sites where the pond/lake is several hectares in area, but could work at sites like Giralang Pond, Isabella Pond and Lower Stranger Pond.
- Most sites would benefit from the **retrofit** of additional stormwater treatment in their upstream catchment, in order to improve water quality arriving at the pond. Upstream of ponds, treatment systems should include measures to treat gross pollutants, organic material and coarse suspended solids.
- The Coombs Ponds are a particular case where they are still coping with significant construction sediment loads in their catchments. These ponds should be reassessed once they settle down to more typical water quality conditions.

If any new large ponds and lakes are constructed in the ACT, they should include:

- Better staging of development, which would reduce the build-up of construction stage sediment in large ponds and lakes. While ponds are very well suited for removing sediment from stormwater, when sediment loads are high (such as during construction), temporary sediment basins are more appropriate. Staging is discussed further below.
- Better upstream pre-treatment, particularly targeting coarse suspended solids and organic matter. This could include a sediment basin immediately upstream of the main pond, with the sediment basin designed with a maintenance drain and access for sediment removal equipment.
- If they cannot be sized appropriately for their catchment (e.g., Giralang, Dickson and Lyneham are all very small for their upstream catchments), then they should be located offline with a high flow bypass.
- Water depths less than approximately 2.5-3.0 m to minimise the risk of stratification.
- Extended detention controlled by a riser outlet to achieve a 2-3 day notional detention time.
- More extensive macrophyte planting around the edges, including shallow and ephemeral zones.
- A mechanism to control water levels manually (at least within the extended detention zone) in order to facilitate maintenance.

A better approach for future regional infrastructure to be constructed in situations where significant greenfield development will take place upstream would be to design a system which can operate in different modes at different stages of its life. In the first stage, the system should be designed as a sediment basin for construction-stage runoff. This approach allows bulk earthworks and major civil infrastructure to be installed for the regional stormwater treatment system at the same time that other regional infrastructure is constructed. A regional sediment basin would help prevent sediment loads from passing downstream into receiving environments such as the Molonglo and Murrumbidgee Rivers. Normally sediment basins are smaller than regional ponds, they are easily drained and coarse sediment can be easily removed. Construction-stage sediment is generally relatively free of contaminants and can therefore be reused as fill material. The estate developer could be made responsible for cleaning out sediment at the completion of their works. The system should be converted to a stormwater polishing system only after estate development and the majority of private developments are complete. Landscaping works should be undertaken at this time.

Small ponds and wetlands

Small ponds and wetlands are becoming more popular as a stormwater treatment measure, particularly since the ACT WSUD Code (2009) set mandatory pollutant load reduction targets for new development.

We have categorised the water bodies in this review into two categories, loosely based on their size. The small ponds and wetlands:

- have a surface area less than 1 ha
- typically include macrophyte zones
- are typically shallower than 1.5 m
- are typically located offline or with a small upstream catchment
- have been designed mainly for water quality treatment
- are local infrastructure which serves a single development/estate, suburb or even smaller area.

The small ponds and wetland reviewed in this project are listed in *Table 4*. These include a diverse mix of designs, from simple online systems to more complex offline systems with extended detention and recirculating flows.

Table 4: Small ponds and wetlands reviewed

Name	Type of system	Surface area (m^2)
Crace wetland (corner Gundaroo Drive and Abena Avenue)	Recirculating wetland connected to adjacent pond	TBC
Norgrove Park wetland (Kingston foreshore)	Both an online stormwater wetland as well as recirculating wetland connected to adjacent pond	TBC
Emu Bank wetland (Eastern Valley Way, Belconnen)	Both an offline stormwater wetland and recirculating wetland connected to Lake Ginninderra	4,857
David Street pond	Offline pond	1,662
Pond at corner of Ian Potter Crescent and Tesselaar Street, Gungahlin	Online pond	2,379
Two ponds downstream of Point Hut Pond	Online ponds – waterway stability	4,879

Smaller ponds and wetlands have become more prevalent in the ACT since the introduction of the ACT WSUD Code (2009), which includes mandatory stormwater pollutant load reduction targets for new development. Ponds and wetlands can be used as part of a treatment train to meet these targets.

However, small ponds and wetlands first became popular in the early 2000s and the list above includes a few examples from this time – David Street (2001), Ian Potter Crescent/Tesselaar Street (2004) and Norgrove Park wetland (2004).

The Crace wetland and Emu Bank wetland are the newest examples of wetlands in the ACT, built within the last few years.

Note that the two ponds downstream of Point Hut Pond are a special case which do not function as water quality treatment systems and are better thought of as part of the modified waterway between Point Hut Pond and the Murrumbidgee River.

Appropriateness

The design of ponds and wetlands for stormwater quality treatment has undergone a gradual transition since the 1980s and 90s. The role of extended detention is better understood and it is used more often. In general, designs have moved away from large online systems dominated by open water, towards smaller systems, located offline with a more extensive macrophyte zone. This shift has come about due to:

- A greater focus on nutrients, trace toxicants and other fine, colloidal and dissolved pollutants in stormwater
- more research into the processes in ponds and wetlands
- more sophisticated modelling tools to help design stormwater treatment systems
- the availability of more design guidance for stormwater treatment systems
- mandatory stormwater quality targets for new developments.

The South East Queensland Healthy Waterways Partnership released design guidelines for WSUD, including constructed wetlands, in 2006, and these became (and remain) the definitive design guideline for constructed wetlands in Australia. However, there are few (if any) examples of wetlands in the ACT which have been designed in line with the principles in these guidelines. Each of the small ponds and wetlands in this review has different features. A summary of key features is provided in *Table 5*. Each has been designed to site-specific objectives and to suit specific site constraints, as well as reflecting the design practice of the time.

It is difficult therefore to comment on the appropriateness of this asset category as a whole, but each of the features is assessed individually here. In the case of small ponds and wetlands, offline systems are generally more appropriate than online (with a possible exception where the catchment area is very small), as online systems are subject to very high hydraulic and pollutant loading. Online systems are easily damaged by high flows and it is very difficult to support healthy macrophytes in these systems. Norgrove Park is an example where this issue is evident.

Small ponds and wetlands are appropriate to treat storm flows, providing that:

- there is adequate pre-treatment of litter, debris and suspended solids
- high flows are bypassed around the system (noting that the vast majority of storm flows and pollutant loads are transported in small events with moderate flows)
- there is extended detention and a riser outlet to ensure a long residence time in the system.

Wetlands can be used successfully to treat recirculating flows. This is a common approach where they are used adjacent to an open water body (e.g., Crace, Norgrove Park). By recirculating flows through the wetland, water quality can be improved in the open water body by providing continual treatment and reducing the effective residence time. Note that a recirculating wetland does not need extended detention or a riser outlet, as the recirculation pump can be sized for an appropriate flow rate and residence time.

Shallow depths are generally preferred in order to reduce the likelihood of anaerobic conditions, support a healthy macrophyte zone and improve pollutant removal in ponds and wetlands. Deeper zones may be appropriate to target sediment removal and provide some open water for aesthetic/habitat purposes, however shallow zones (less than 0.3 m) are better able to support macrophytes and achieve significant nutrient removal.

Extended detention, controlled by a riser outlet to retain flows in the pond/wetland for a notional detention time of 2-3 days, is recommended as an integral part of a stormwater treatment wetland; however, there are few examples in the ACT where effective extended detention is included in wetland systems.

Likewise, there are few examples in the ACT of well-functioning macrophyte wetlands. Macrophyte wetlands which are protected from high flows are able to support biofilm systems which are highly effective for removal of dissolved pollutants including nutrients. Macrophytes do best in ephemeral to shallow (<0.3 m) zones with extended detention (up to 0.5 m) and low velocities.

Table 5: Key features of the small ponds and wetlands included in this review

Name	Online/ offline	Storm flows	Recirculation	Approx. Depth (m)	Extended detention	Macrophyte coverage
Crace wetland (corner Gundaroo Drive and Abena Avenue)	Offline		✓	<0.5	None	60%
Norgrove Park wetland (Kingston foreshore)	Online	✓	✓	<0.5	None	50%
Emu Bank wetland (Eastern Valley Way, Belconnen)	Offline	✓	✓	0.1-1.9	250 mm	5%
David Street pond	Offline	✓		0.9 (avg)	Minimal	10%
Pond at corner of Ian Potter Crescent and Tesselaar Street, Gungahlin	Online	✓		<1.0	Minimal	50%
Two ponds downstream of Point Hut Pond	Online	✓		>1.0	None	10%

Objectives

While the small ponds and wetlands discussed above have a wide range of design features, most of them have clearly been designed with some water quality treatment purpose. Some are more focused on storm flows and some on recirculating flows, however most (with the possible exception of the ponds downstream of Point Hut Pond) are clearly intended to improve water quality.

Small ponds and wetlands also address other objectives such as flow attenuation, landscape and amenity, habitat and biodiversity, community engagement and education. David Street pond is a good example where the objectives have been articulated and include all of these aspects.

We understand that the objectives at Emu Bank were mainly focused on landscape and amenity rather than water quality improvement – the wetland is very small for the upstream catchment, therefore water quality benefits are small.

Further information on the objectives of specific projects may be available if we are able to review concept design reports (or similar).

What performance issues are occurring?

There is limited event-based stormwater quality monitoring data available for small ponds and wetlands. The possible exception is Norgrove Park wetland, where we have seen summary results from a study into pollutant load removal, however it is unclear whether pollutant removal was assessed during storm events or recirculating conditions. More information about the methodology would allow a realistic assessment of this data. At this stage it is impossible to fully assess the performance of small ponds and wetlands as stormwater quality treatment systems.

Some information is available on the in-pond water quality issues – for example from Waterwatch monitoring at David Street and Norgrove Park. Urban ponds commonly display long-term management issues including poor in-pond water quality, algal blooms and weed outbreaks. Low dissolved oxygen, high nutrient concentrations and high chlorophyll-a are common issues and all of these issues are seen to some extent at David Street and

Norgrove Park. As organic matter accumulates and breaks down in a pond, dissolved oxygen levels drop and decomposition is anaerobic. Under these conditions, many pollutants which are normally adsorbed to suspended solids, including phosphorus, are re-released into the water column. Odours are common, algal blooms can be triggered as a result and, in extreme cases, the low DO levels can cause fish kills. In deeper systems, temperature stratification exacerbates the issue by discouraging oxygen transfer from shallow to deep water. A long-term build-up of accumulated pollutants can also exacerbate the issue.

Many jurisdictions in Australia have therefore moved away from ponds as stormwater treatment systems, however wetlands remain popular. Shallow macrophyte wetlands can avoid many of the issues associated with ponds, as they are not prone to anaerobic conditions and macrophytes tend to take up nutrients before algal blooms and weed outbreaks take over.

One of the common issues seen in the wetlands was poor establishment of macrophytes. This is probably due to different reasons in different locations. For example:

- At Emu Bank it appears that macrophytes were only ever planted in small areas of the wetland, and then most of the establishing seedlings were drowned before they were sufficiently established.
- At Norgrove Park the wetland is subject to high storm flows which cause physical damage and inhibit the establishment of macrophytes.
- At Crace, macrophyte establishment has been the most successful of any site, but it appears that some species have thrived while others have done poorly.
- In the other systems, it does not appear that macrophytes have been planted beyond the edges of the ponds. *Typha* and *Phragmites* seen in these systems are common sedges that could have self-propagated. Beyond the edges, David Street, Ian Pottter/Tesselaar and the ponds below Point Hut Pond are probably too deep to support macrophytes.

Other performance issues are more specific to each site – for example the diversion design at David Street and issues caused by high flows at Norgrove Park.

Note that maintenance activities at the small ponds and wetlands in the ACT are generally minimal. Civil maintenance is largely confined to management of any GPTs at inlets, while landscape maintenance is confined to mowing and weed spraying around the edges. Neither the civil nor landscape maintenance teams have clear responsibility for maintaining the water body itself. Norgrove Park is an exception, where this asset is still being maintained by LDA and has not yet been handed over to TAMS. It appears that Norgrove Park has an active maintenance regime including the water body itself, however, to date we have not been able to obtain the relevant information from the LDA.

As with Canberra's large ponds and lakes, desilting is unplanned and only undertaken as a reactionary measure. Generally, designs have not included any provision for desilting (e.g., maintenance drain, access for machinery, separate sediment zone) and therefore when it has been undertaken, it has not been straightforward. TAMS reported that desilting at David Street was undertaken with a long-reach excavator without draining the pond. Trees had to be removed for this exercise.

Why are these performance issues occurring?

Many of the issues occurring at small ponds and wetlands come back to errors at the design stage. A related issue is that ACT government review and approval processes lack consistency around small ponds and wetlands (e.g., inconsistency between Territory Plan requirements and Asset Acceptance requirements). In addition, there is limited capacity within the ACT government to assess the wide variety of pond and wetland designs which are being developed.

Key issues are given inadequate consideration at the design stage including:

- appropriate design flows and diversion/high flow bypass design
- appropriate pre-treatment upstream
- appropriate water depths

- provision of extended detention with an appropriate detention time
- maintenance access into and around ponds
- ensuring maintenance schedules and activities required by the design are reasonable and appropriate for the resources and equipment available
- vegetation species selection and placement, suitable for local conditions.

The establishment stage is a crucial phase in the life of a vegetated stormwater quality treatment system, but it is often undertaken poorly and this appears to often be the case in the ACT. Construction contracts generally do not allow for an appropriate establishment phase and there is always pressure to finalise construction and asset handover as quickly as possible. Stormwater treatment systems are often built by civil contractors who are focused on the civil elements and lack specialist skills in vegetation establishment. Establishment of wetland vegetation is a particularly specialised skill which is lacking.

Operation and maintenance could be improved and the key issues here are identifying responsibility for maintenance of the water body itself and allocating appropriate resources.

Opportunities to improve performance

None of the small ponds and wetlands have urgent issues which need to be addressed immediately. Therefore, each of them could be **maintained** in its current state for some time.

A couple of systems may benefit from simple **renewal** to remove accumulated sediments and reduce in-pond water quality issues. However as discussed above, this has been done before at David Street pond and the same problems tend to return as sediment and organic matter continues to accumulate in the pond.

Therefore, many of these systems would benefit from **redesign** works to change the way that they function. Some of the key physical design features which should be adopted in small ponds and wetlands are:

- high flow bypass (so the system operates offline)
- separate sediment basins upstream of the macrophyte zone or main open water zone
- shallow macrophyte zones
- extended detention, controlled by a riser outlet for a 2-3 day notional detention time
- manual water level control to facilitate vegetation establishment and maintenance.

Others need **rectification** works to ensure that key features function as originally intended, for example:

- bunding (to avoid short-circuiting) at Crace
- scour and erosion at Norgrove Park
- the diversion structure at David Street
- macrophyte plantings at Emu Bank.

Many of the systems would also benefit from the **retrofit** of additional treatment measures to pre-treat stormwater in the catchment upstream. The Norgrove Park wetland, Emu Bank wetland and David Street pond are particularly small for their catchment areas.

Note that the two ponds below Point Hut Pond are not in an appropriate location to provide water quality treatment, as any treatment benefit which could be achieved in a pond has already been achieved at the Point Hut Pond upstream. There is therefore little benefit in including more ponds in a series below Point Hut Pond. These ponds can be viewed as part of the waterway and the key issue which needs to be addressed is the stability of the embankment.

Swales and waterways

Swales and waterways have always been used in stormwater management in the ACT, however the design approach for these systems has evolved over the years. While older systems were designed principally for conveyance and were designed to undertake this task as efficiently as possible, newer systems have gradually evolved to incorporate more of a stormwater treatment role.

The swales and waterways reviewed in this project are listed in *Table 6*. These range from small systems with an individual street as their catchment, to large waterways with catchments spanning several suburbs. They include systems constructed in the 1980s (Knoke Avenue Gordon), 2000s (Gungahlin, Franklin and Bonner) and 2010s (Harrison and Crace).

Table 6: Swales and waterways reviewed

Name	Type of system
Mabo Boulevard, Bonner	Median swale
Margaret Tucker St, Bonner	Overland flowpath
Helby Street, Harrison	Small swale/overland flowpath
Trephina Street, Harrison	Small swale/overland flowpath
Medhurst Crescent, Crace	Overland flowpath
Plimsoll Drive, Casey	Median swale
Tsoulias Street, Gungahlin	Median swale
Franklin constructed waterway (Gungaderra Creek)	Engineered waterway with significant stormwater treatment role
Knoke Avenue constructed waterway, Gordon	Engineered waterway with limited stormwater treatment role

Note that the swales and waterways include some which are clearly intended as stormwater treatment systems and others which have little or no stormwater treatment role. Many of them lie somewhere on a spectrum between conveyance systems for overland flows and stormwater treatment systems.

Appropriateness

Vegetated swales and waterways are very effective at removing sediment from stormwater, including fine sediment and sediment-bound pollutants, providing that:

- stormwater is able to drain to the swale
- swales are well-vegetated
- velocities are reasonably low
- swales are stable.

Swales are not particularly effective for nitrogen removal and therefore unlikely to be able to meet WSUD Code targets on their own. However, as part of a treatment train, they are an ideal pre-treatment step upstream of a pond or wetland. They can address fine sediment loads and sediment-bound pollutants that are missed in GPTs but which are problematic in ponds and wetlands downstream.

Swales and waterways can be low-maintenance stormwater treatment systems. For example, the Franklin waterway has been noted by TAMS as a low-maintenance system, which is providing significant water quality benefits. Designed well, swales and waterways can be robust systems which require relatively little maintenance effort.

Swales and waterways can also provide other benefits beyond water quality treatment including:

- landscape and amenity

- habitat and biodiversity
- recreational opportunities
- floodways for conveyance of high flows
- attenuation of low and medium flows.

Key risks for swales and waterways in the ACT include that:

- Local soils are highly erodible, particularly when grades are steep. Designers need to consider velocities and shear stresses and provide appropriate surface treatment.
- With tight maintenance budgets, there is limited capacity for maintenance staff to manage weeding, and therefore vegetation needs to be robust and well-established from the outset.

A key question regarding swales and waterways is what proportion of flows should be conveyed underground versus above ground. Many of the older swales and waterways in the ACT include low flow pipes and channels which convey a large proportion of the total runoff, as well as a large proportion of total pollutant loads. These flows are the highest priority for treatment, so a challenge is to turn traditional drainage design around to keep the low flows on the surface. The pipe system is still important to convey high flows which may otherwise cause scour and erosion.

Objectives

The swales and waterways included in this review differ in their objectives and often have multiple objectives. Some have been constructed to act as stormwater treatment systems but most have primarily been designed to convey overland flows in major rainfall events. Some swales consist of vast areas of turf whilst others have extensive planting of native grasses, sedges and shrubs. Many of the swales combine multiple features such as treatment of local road runoff and conveyance of overland flows. The objectives of the studied swales and waterways are outlined in *Table 7*.

Table 7: Swale and waterway objectives

Name	Swale/waterway objectives ('1st' denotes primary objective; '2nd' denotes secondary objective)			Physical features	
	Treatment of small local catchment	Treatment of large upstream catchment	Overland flow route	Low flow pipe or channel present	Significant native vegetation
Mabo Boulevard, Bonner	✓ (1st)			✓	✓
Margaret Tucker St, Bonner	✓ (2nd)		✓ (1st)	✓	✓
Helby Street, Harrison	✓ (2nd)		✓ (1st)		✓
Trephina Street, Harrison	✓ (2nd)		✓ (1st)	✓	✓
Medhurst Crescent, Crace			✓ (1st)	✓	
Plimsoll Drive, Casey	✓ (1st)		✓ (2nd)	✓	✓
Tsoulias Street, Gungahlin	✓ (2nd)		✓ (1st)	✓	
Franklin constructed waterway (Gungaderra Creek)		✓ (2nd)	✓ (1st)		✓
Knoke Avenue constructed waterway, Gordon			✓(1st)	✓	

What performance issues are occurring?

There is currently no known stormwater quality monitoring data available for the swale systems. At this stage it is therefore impossible to fully assess the performance of swale systems as stormwater quality treatment systems in the ACT.

However, to date our review has allowed us to observe the performance of swale and waterway systems at a "macro" scale. We have been able to see how stormwater physically interacts with these systems and make a broad assessment of their function. The swales that have performed the worst have been Mabo Boulevard and Plimsoll Drive. Knoke Avenue waterway also has significant erosion issues. Other swales have minor issues. Key observations common to many of the swale systems have been:

- Generally, the catchments draining directly to the swales are relatively small and therefore there would be little improvement in water quality in the scheme of the wider catchment. Often there is a small road catchment draining to a vast swale, such that the runoff would generally not reach the swale invert but rather be absorbed by the vegetation and soils in the space between the kerb and the swale.
- Further to the above point, the swales often appear to be a missed treatment opportunity due to the inclusion of a low flow stormwater pipe. The majority of runoff from upstream areas in frequent low intensity rainfall events passes into the low flow pipe and on to the downstream receiving waters (often a pond) with no treatment by the swale and often only coarse litter removal, allowing sediment to enter the pond.
- Castellated gutters often have issues with blockage of the kerb gaps by accumulated sediment. If left for a long time turf or weeds can grow in the accumulated sediment leading to further blockage. The blockage of the gaps leads to road runoff bypassing the gaps. Instead of the stormwater entering the swale in a distributed manner, runoff from a length of road often enters the swale in a concentrated location. The arrangement of the gaps also prevents water from passing through the gaps easily.
- Erosion is seen where velocities within swales are high and there is an inadequate surface treatment for the velocities experienced. The most notable examples of scouring are at the Plimsoll Drive swale and Knoke Avenue waterway, but there is also some at Mabo Boulevard.
- TAMS has had some difficulty with maintaining vegetation in swales (other than turf) – a key example is Mabo Boulevard. However, most of the swales and waterways have proven to be robust systems, suggesting that appropriately selected and well-established native vegetation can be easy to maintain in a swale or waterway.

Why are these performance issues occurring?

In most cases, despite minimal maintenance, the swale and waterway systems are in reasonable condition. In some cases (e.g., Harrison) this may be due to the fact that they are not actually treating significant stormwater flows, therefore they are somewhat protected from sediment loads, weed propagules, litter, etc. The design philosophy around swales and waterways in the ACT has historically been that they are primarily conveyance systems, used to deliver water to GPTs and ponds. It is only recently that swales have been considered in terms of their potential stormwater treatment role, and this may explain why most of them have been designed conservatively, to treat only small stormwater catchments.

The performance of the swales and waterways therefore needs to be considered in the context that most of the systems are designed for conveyance of large overland flows. It is likely that they have never been tested to their design capacity (e.g., 100 year ARI overland flow). Many of the systems are effectively designed for extreme conditions which are very unlikely to have occurred to date in the life of the system.

The most common issue which was seen at many of the swales was poor performance of castellated gutters. A common design issue with the castellated gutters is that insufficient fall is provided across the kerb gap. In addition to this, there is often no dropdown provided from the back of the kerb gap to the swale surface. It is important that there is a pronounced dropdown from the back of the kerb to the top of the turf (when the turf is at its maximum height). This generally means that the topsoil should be finished no higher than 100-150mm below the back of kerb level. Based on the drawings we have reviewed to date, this detail is generally missing from design drawings and is not specified elsewhere.

Poor design documentation also appears to have been a factor at Plimsoll Drive and potentially also at Mabo Boulevard. Design drawings do not show enough detail on proposed levels, and therefore many sections have been constructed with inappropriate topography, including steep slopes and deep profiles.

Some of the issues found with swale and waterway systems are related to the local design standards and specifications, which cover only the hydraulic requirements without considering the detailed requirements that swales require for longevity. Whilst it is stated that "waterway [scour] protection must be provided to suit the local physical and scour characteristics" there may not be sufficient information to ensure that this design objective is met.

The requirement for swales and waterways is that the flow velocity must not exceed 2 m/s, but this criterion does not guarantee the stability of a swale or waterway. The standards may benefit from additional fine level details such as the acceptable flow velocity for different surface treatments (e.g., grass vs rock).

Beyond the design stage, other factors impacting on the performance of the swales are more site-specific. For example:

- the construction stage has been particularly problematic at Plimsoll Drive
- vegetation establishment (and condition at handover) was a particular issue at Mabo Boulevard
- erosion in the Knoke Avenue waterway has emerged during longer-term operation and maintenance issue. To date, the methods used to address erosion at this site have not been particularly successful in addressing the processes causing the erosion – the problem has simply shifted elsewhere.

Opportunities to improve performance

In terms of the specific systems reviewed in this project, there are a few options available. Most of the swale systems, despite the fact that they don't treat much stormwater, are stable and reasonably well vegetated (even if only short turf), and could be **maintained** as they are without causing negative impacts.

Renewal is recommended for selected systems which have been impacted by scouring or erosion, or where vegetation is performing poorly. In general, the swales and waterways that are performing the best from a stability perspective have the following design features:

- generous dimensions and gentle grades
- no features which concentrate flows
- well established vegetation
- turf that is robust under high velocities (and can also provide a useful buffer zone around native vegetation).

The waterway at Franklin treats significant flows and remains stable and effective, while the swales at Harrison are well protected by large grass buffers.

Rectification works could be undertaken to improve the function of castellated gutters. Where required the turf should be stripped and topsoil level lowered to ensure that there is a drop from the back of the kerb gap to the turf surface. Note that in some cases, this may require re-grading a significant width in order to work effectively. Alternatively, where levels are constrained, instead of dropping the entire strip behind the kerb, a small hole around 200mm deep could be excavated behind each gap to act as a sediment trap and stilling basin or soakaway for all flows that pass through the gap.

If there is a desire to improve the treatment performance of the swales, **redesign** works would be required. From a water quality treatment perspective, there are significant opportunities to increase the treatment capacity of most the systems reviewed in this project. Options include directing more stormwater to the swales – particularly low flows from frequent rain events – and maximising contact between stormwater and vegetation.

The key limitation to this approach is that most of the systems have been designed for conveyance and this function needs to be maintained in order to avoid any impacts on flooding.

In general, swale and waterway systems would also benefit from updated design standards and specifications which address the water quality treatment role of swales and waterways as well as their conveyance function, and design guidance on:

- designing to maximise stormwater treatment performance
- designing systems to avoid scour and erosion (to replace prescriptive requirements)
- vegetation selection and establishment
- designing habitat features such as pools and riffles.

Melbourne Water's *Constructed Waterways in Urban Developments Guidelines* (2009) provide a good starting point – much of the advice therein is relevant to the ACT.

Bioretention systems and rain gardens

Bioretention systems and rain gardens have become popular as a stormwater treatment measure elsewhere in Australia over the last decade. They are sometimes preferred over wetlands because:

- they can achieve the same nutrient removal in a smaller footprint
- they are better suited to steep sites, where it can be difficult to accommodate a large water body
- they can be scaled up or down, from extensive basins to individual tree pits
- in general, when well designed and established, they are low maintenance systems.

Since the ACT WSUD Code (2009) set mandatory pollutant load reduction targets for new development, some bioretention systems have been constructed in the ACT. Some of the systems at Forde were constructed around five years ago and most of the systems at Crace have been constructed within the last 2-3 years. Bioretention systems can be used on their own or in a treatment train to meet the WSUD Code targets.

Note that the terms "bioretention system" and "rain garden" are essentially interchangeable. However, in keeping with general use in the ACT, we have referred to the streetscape systems as rain gardens and the larger basin at Crace as a bioretention system.

The bioretention systems and rain gardens reviewed in this project are listed in *Table 8*. These are mainly streetscape systems and all of them are located at Crace and Forde.

Table 8: Bioretention systems and raingardens reviewed in this project

Name	Type of system	Surface area (each rain garden) (m^2)
Bioretention basin off Medhurst Crescent, Crace	Larger basin with saturated zone	775
Abena Avenue, Crace	16 streetscape rain gardens	30-75
Ultimo Street, Crace	6 streetscape rain gardens	30-55
Digby Circuit, Crace	7 streetscape rain gardens	6
Langtree Crescent, Crace	31 streetscape rain gardens	6
Turbayne Crescent, Forde	3 streetscape rain gardens	9
Zakharov Avenue, Forde	61 streetscape rain gardens	4

Appropriateness

A question has been raised over whether bioretention systems are at all appropriate in the ACT, due to the fine dispersive nature of the local soils. This is a valid concern given that many bioretention systems have become clogged with fine sediment within a few years of their construction.

However, it is important to distinguish between construction-phase and long-term sediment loads. During the construction phase (both estate construction and building on private lots), sediment loads are high and a bioretention system is *not* an appropriate treatment system at this stage. This is the case all over Australia, regardless of the soil type and regardless of how effective local erosion and sediment control practices may be. Even with the best measures in place, sediment loads are still significantly higher than the long term and bioretention systems are easily smothered.

In a relatively stable catchment (e.g., once 90-95% of house construction is complete), bioretention systems can be used successfully in any soil environment. There are many examples around Australia where they are used in similar soil environments to the ACT – for example western Sydney's soils are fine dispersive clays, similar to the ACT.

A second issue with bioretention systems in the ACT is whether they are appropriate from a maintenance perspective, given the current limitations in the maintenance budget and capacity of maintenance staff. TAMS have reported that they have serious issues with bioretention systems, including that:

- They have not been provided with adequate training or information on how to maintain them.
- They do not have capacity to undertake the routine maintenance activities required (e.g., hand weeding is recommended in bioretention systems to minimise the impact of herbicides on downstream waterways, however it appears that hand weeding is generally not practiced at all by the Parks and City Services group).
- There is a belief that the whole filter and all of the vegetation within it (including street trees in many systems) will need to be replaced in approximately 10 years, at significant cost and with a significant impact on the streetscape.
- The use of streetscape rain gardens creates a very large number of small systems that require maintenance, which is potentially an inefficient solution with high maintenance costs.

We believe that at present TAMS are not maintaining any rain gardens in the ACT. This is a serious issue which needs to be resolved before any new rain gardens are constructed. This also means that many of the rain gardens we have seen in this review have not been maintained for several years.

A third key question is whether street trees are appropriate in bioretention systems. Generally, in the ACT, street trees are relatively unconfined in wide verges, and are able to grow to a significant size. However, a (lined) bioretention system effectively confines a street tree to a small pit with a relatively shallow depth.

As discussed below, our review has also found that the bioretention systems constructed to date have some serious design and construction issues. All of this means that there have been insufficient opportunities in the ACT to test a well-designed and well-established bioretention system operating under an appropriate maintenance regime.

Objectives

It is reasonably clear that all of the bioretention systems in this review have been intended to provide stormwater treatment. They have probably been included in estate designs to meet the stormwater quality treatment targets in the WSUD Code (2009). However, bioretention systems are also designed for landscape and amenity outcomes, and they can also provide habitat and biodiversity value. At Crace, interpretive signage at the large bioretention basin provides a simple opportunity for community engagement and education.

What performance issues are occurring?

There is currently no known stormwater quality monitoring data available for bioretention systems. At this stage it is therefore impossible to fully assess the performance of bioretention systems as stormwater quality treatment systems in the ACT.

However, our review has allowed us to observe the performance of bioretention systems at a "macro" scale. We have been able to see how stormwater physically interacts with these systems and make a broad assessment of their function. Key observations common to many of the streetscape systems have been:

- The design of stormwater drainage systems (including both lot drainage and streetscape drainage) does not appear to have been well-integrated with the design of bioretention systems. Many systems have little or no contributing catchment area.
- Typically, there is a minimal (or sometimes no) drop from the gutter to the filter surface. This makes it hard for any water to enter the bioretention system and means that there is limited capacity for extended detention. Therefore, very little stormwater can be treated in most of the streetscape systems.
- Even where there is some drop from the gutter to the filter surface, many systems have poorly designed inlets, which block easily.
- While most of the trees in bioretention systems appear healthy, understorey vegetation establishment is mixed. There are probably numerous reasons for this, including:
    - poor establishment before handover
    - lack of maintenance since handover
    - lack of stormwater entering the system, which leaves vegetation in drier conditions than intended
    - species selection has probably been an important factor – it appears that some species have thrived while others have struggled.
- While most systems were relatively weed-free, some had significant weeds. This is possibly due to the limited maintenance they have received as well as poor establishment of native vegetation, which has allowed weeds to colonise the system.
- Some systems (particularly at Crace) have been severely damaged by construction-stage sediment loads, dumping of construction waste and physical construction impacts. However, it is important to note that this was not the norm and most of the systems we looked at appeared to have been well-protected from construction-stage damage.
- Some systems (particularly at Forde) had significant quantities of residential waste (e.g., grass clippings and other garden waste) dumped within them.

In most cases, despite the lack of maintenance, streetscape bioretention systems were in reasonable condition. However, this may be due in part to the fact that they are not actually treating significant stormwater flows, therefore they are somewhat protected from sediment loads, weed propagules, litter, etc.

Why are these performance issues occurring?
There are key issues arising at many stages in the life cycle of bioretention systems in the ACT, however many issues are arising at the design stage. Most of the bioretention systems included in this review have fundamental design flaws, including the following common problems:

- No, or insufficient, allowance for extended detention
- poor inlet design (inlets which block easily)
- poor under-drainage design. Some systems lack a drainage layer. Many include filter socks on the drainage pipe, many lack flushing points or no detail was provided on how to finish flushing points appropriately.

There are good quality detailed design guidelines, typical drawings and standards available for bioretention systems elsewhere in Australia. Design guidance on these key hydraulic design details (extended detention, inlets and outlets) would be directly transferrable to the ACT, and therefore these issues should not be occurring at the design stage. There are some other potential design issues which are more locally-specific and require further review (once we've had a better chance to review design drawings and other documentation) including species selection and filter media specification.

After the design stage, other factors are compounding performance issues, such as:

- During establishment, poor staging has allowed some systems to be impacted by construction stage sediment loads and other damage.
- During asset handover, systems with significant design and construction issues appear to have been approved – the large bioretention system at Crace is a good example.
- During operation, some residents have dumped waste in bioretention systems, suggesting that they do not understand these systems.
- Maintenance has been completely lacking.

The large number of issues with bioretention systems is partially related to the fact that specialist knowledge and experience may be limited in local developers. A related issue is that there is limited capacity within the ACT government to assess the appropriateness of bioretention system designs and constructed outcomes.

The breakdown the in maintenance of bioretention systems and rain gardens is a fundamental problem that needs to be addressed before more bioretention systems are built in the ACT. Well-designed bioretention systems are low-maintenance systems. However, a poorly designed, poorly constructed or poorly established bioretention system can quickly deteriorate into a maintenance problem. This has occurred in several cases (the Crace bioretention basin is a good example) and could be one of the key reasons why there has been a strong reaction from maintenance staff.

Opportunities to improve performance

Before any new bioretention systems are constructed or substantial modifications are undertaken to existing systems, bioretention system maintenance needs to be given more consideration in the ACT context. Bioretention system design needs to take into account the capacity, skills and resources of local maintenance staff. This might mean locally-specific design features to make systems easy to maintain with existing equipment and using common existing maintenance practices. Appropriate guidance and training is required to equip staff with the necessary knowledge and skills to successfully maintain bioretention systems.

Due to the large number of small systems, streetscape rain gardens do have higher maintenance requirements than other stormwater treatment systems. In the context of a very limited maintenance budget, they may not be a particularly appropriate option in the ACT – at least in the short term. The question of trees in bioretention systems also needs more thought in terms of long-term maintenance requirements. While tree replacement is unlikely to be required after 10 years, it is an issue that may come up within 20-30 years, i.e., sooner than a street tree may otherwise be replaced.

Larger bioretention basins are more likely to be appropriate in the short-term, however there are still fundamental maintenance questions which need to be addressed. All bioretention systems require weeding, and this is best achieved by hand. If done regularly, this is not a large task, however if weeds go unchecked for a significant length of time, this can quickly become a very significant task. For example, in another recent rain garden review project, landscape maintenance staff at Marrickville Council reported that if they weeded bioretention systems each month, the task was small, however if they left systems much longer, it quickly grew into a significant effort. If ACT Government staff are unable to undertake hand-weeding then alternative maintenance pathways need to be considered and appropriately resourced.

Bioretention systems would benefit from:

- training for local industry and government staff involved at all stages of the life cycle
- more careful scrutiny at DA, design review and asset acceptance stages
- in new estates, changes to construction staging and asset handover practices would be beneficial so that bioretention system can be built out later in the process, after house-building is complete
- education of local residents both to prevent issues of dumping in rain gardens and also so that residents can potentially play a role in simple maintenance tasks such as hand weeding and clearing inlets (a trial could be instituted at Forde and/or Crace).

In terms of the specific systems reviewed in this project, there are a few options available. Most of the streetscape systems, despite the fact that they don't treat much stormwater, are stable and reasonably well vegetated, and could be **maintained** as they are without causing negative impacts. **Renewal** is recommended for selected systems which have been impacted by construction-stage sediment, dumping, or similar issues, or in cases where understorey vegetation and/or street trees are absent or in poor health. Sediment and waste should be removed and vegetation should be replanted. However, this would not restore treatment performance to systems with no extended detention, poor inlet design, etc.

If there is a desire to improve the treatment performance of the streetscape rain gardens, **rectification** works would be required. The following options are recommended for further consideration:

- Minor works could be undertaken to address inlet design limitations and provide extended detention in systems where it is lacking. These works could be undertaken around existing trees, involving simply reducing surface levels and replanting understorey vegetation.
- A more substantial rebuild (essentially a full replacement of the existing rain garden) to address issues with under-drainage would require tree replacement, which is unlikely to be palatable at many sites in the short-term. This option may be more appropriate sometime in the future when street trees need replacing.

As discussed in the individual site reports, we would recommend further investigations and trialling of rectification methods before any large-scale rollout.

The large bioretention basin at Crace could be rectified in line with its current design, but could also benefit from some **redesign** to allow improved maintenance access and provide better pre-treatment. Modification to the flow regime should also be explored and this system could also benefit from the **retrofit** of additional treatment measures to pre-treat stormwater in the catchment upstream.

GPTs

Gross pollutant traps (GPTs) have been used in the ACT since the 1970s. The ACT has a well-established set of design standards for GPTs, which require GPTs to be constructed downstream of all catchments greater than 8 ha that discharge into ponds, urban lakes and receiving waterways.

The ACT design standards for GPTs define "Major" and "Minor" GPTs. Both are concrete basins with a fixed trash rack at the downstream end of the basin. Essentially the Minor GPT is a system designed for a pipe/culvert inlet, while the Major GPT is a system designed for an open channel inlet. Major and Minor GPTs are both designed to site-specific dimensions based on the catchment area, degree of urbanisation, estimated peak flows and pipe/channel dimensions.

In recent years, proprietary GPTs have also been used in the ACT, particularly in greenfield developments.

The GPTs reviewed in this project are listed in *Table 9*. Note that in addition to the GPTs in *Table 9*, we have also seen a large number of GPTs connected to other assets such as lakes, ponds and wetlands.

Table 9: GPTs reviewed

Name	Type
GPT at Barry Drive & Watson Street, Turner	Typical Major GPT
GPT at Flemington Road, Mitchell	Typical Major GPT
GPT Wentworth Ave, Kingston	Proprietary (CDS unit)
GPT at Catchpole Street, Macquarie	Typical Major GPT
GPT at Ibbott Lane, Belconnen	Typical Minor GPT
GPT at Bonner Pond	Typical Major GPT
McCulloch Street trash rack, Curtin	Trash rack on open channel
GPT at De Little Circuit Greenway (Lake Tuggeranong)	Typical Minor GPT

Name	Type
GPT at Athllon Drive, Greenway (Lake Tuggeranong)	Typical Major GPT
GPT at Isabella Pond	Typical Major GPT

Appropriateness

GPTs have been used in the ACT since the 1970s and have proven to be effective for removing the following types of pollutants from stormwater:

- gross pollutants, including anthropogenic litter, leaves and other organic matter transported in stormwater
- coarse suspended solids.

This is supported by GPT cleanout data, which shows that significant quantities of these materials are removed from GPTs. The ACT Major and Minor GPT designs include trash racks which are generally effective for trapping floating gross pollutants, and a concrete basin with a permanent pool, which collects coarse suspended solids and other material which settles easily.

It is often assumed that in trapping suspended solids, GPTs will also trap other particulate matter and pollutants which tend to bind to suspended solids, including phosphorus, trace metals, oil and grease and bacteria. However, we have not seen any information to indicate how effective the Major and Minor GPTs in the ACT are at trapping this material.

Note that the design standards for GPTs suggest that they are designed to trap particles down to 0.04 mm in size – i.e., a coarse silt. However, such fine particles have slow settling velocities. Under ideal conditions (i.e., plug flow with no turbulence), a 0.04 mm particle would have a settling velocity of approximately 1 mm/second (Water by Design Technical Design Guidelines – Chapter 4 Sediment Basins, 2006). Our observations of the Major/Minor GPTs in minor rain events showed that water moved through these systems quickly; the typical residence time in most systems would have been less than 1 minute. In this time, a 0.04 mm particle would settle only 60 mm under ideal conditions (and conditions were generally far from ideal). Note that a coarse sand with a particle size of 1 mm has an ideal settling velocity of 100 mm/s and therefore would settle 6 m in 1 minute (ideal conditions), allowing significant quantities to be trapped in a typical GPT, even under non-ideal conditions.

The assumption that GPTs remove pollutants, such as phosphorus, trace metals, oil, grease and bacteria, hinges on the ability of the system to remove *fine* suspended solids, as these pollutants are generally connected with fine particulate matter. Therefore, if GPTs are not able to remove fine suspended solids then they are unlikely to remove significant quantities of these other pollutants.

Information (e.g., laboratory analysis of sediment samples) on the particle size distribution and quality of sediments removed from GPTs would help to confirm exactly what existing GPTs are removing in terms of fine particulate matter and other pollutants. Established empirical relationships (e.g., the Water by Design Technical Design Guidelines 2006 recommends a modified version of the Fair and Geyer equation) can also be used to estimate the fraction of target sediments removed in sediment basins.

A key concern which has been raised numerous times regarding GPTs in the ACT is that in between cleanouts, accumulated organic matter decomposes anaerobically in the permanent pool. This is supported by common complaints of unpleasant odours from GPTs. We also observed on site at a number of GPTs that at the start of a rain event, as water began to flush through the GPT, the water emerging on the downstream side had a distinct odour of anaerobic decomposition.

When organic matter decomposes in GPTs, nutrients are released into the water column and become bio-available. The effective nutrient load to downstream systems can therefore be increased. Therefore, there is a key question over whether the current GPT designs are the most appropriate for the ACT.

A second key question over the appropriateness of GPTs is their location within the catchment. Most of the older GPTs are located towards the downstream end of the catchment – for example the Sullivan's Creek GPT at

Barry Drive, Turner. The GPTs were originally designed to be the only stormwater treatment measure in the catchment. However older catchments such as Sullivan's Creek are now being retrofit with stormwater quality treatment systems within the catchment, and these systems require gross pollutant and coarse sediment management further upstream. As the ACT's stormwater management objectives have changed, new urban areas have also been designed with more comprehensive stormwater treatment trains which include stormwater treatment further up in the catchment, closer to its source. In this context, large GPTs at the downstream end of the catchment may no longer be the most effective means to capture gross pollutants and coarse suspended solids.

Objectives

GPTs are generally used as a primary step in a treatment train, to reduce loads on downstream stormwater treatment systems such as ponds, wetlands and bioretention basins. As discussed above, they are appropriate for removing gross pollutants and coarse suspended solids, but in most cases they do not remove significant quantities of other pollutants. In the context of the ACT:

- Anthropogenic litter is typically a key stormwater pollutant in commercial and industrial areas, but litter loads tend to be low in residential areas. Our observations of GPTs in the ACT suggest that residential litter loads are generally very low (the key exception is during the house-building phase in greenfield areas, when there are notable litter issues). Anthropogenic litter includes floating, settleable and neutrally buoyant materials, and each of these can be targeted in GPTs.
- Organic matter (e.g., leaves, grass clippings and other organic debris) is an important stormwater pollutant in the ACT, due to the prevalence of trees and mown grass in both the public and private domain. Organic matter is also a key pollutant which impacts on water quality in lakes and ponds, due to its ability to release nutrients as it breaks down.
- Coarse suspended solids are present, however in general the soils in the ACT are fine-grained clays and therefore these are also a key stormwater pollutant.

Maintenance is a key consideration in GPT design, as there is an inherent tension in GPT design between the pollutant trapping efficiency and the required maintenance effort. Currently, a large proportion of the ACT's budget for maintaining stormwater treatment systems is spent on cleaning out GPTs. Even with this focus on GPTs, the budget is stretched and many GPTs are not cleaned as often as they should be. Therefore, any proposed changes to GPT design need to carefully consider the maintenance burden.

What performance issues are occurring?

There are a wide range of performance issues we have observed in GPTs. Key findings can be summarised in terms of the Major/Minor and proprietary GPTs.

Major/Minor GPTs are:

- Generally trapping small quantities of anthropogenic pollutants, as many are located on predominantly residential catchments with low litter loads. However, even with low litter loads, many allow floating litter to wash out easily when water overtops the trash rack. They also allow fine floating material to pass through the trash rack.
- Generally trapping significant quantities of organic matter, however due to the presence of a permanent pool, this material is decomposing anaerobically and likely to be releasing nutrients into downstream waterways. Due to the relatively low frequency of cleanouts, significant decomposition and nutrient release is likely to occur between cleanouts.
- Generally trapping significant quantities coarse suspended solids but unable to trap any significant quantity of fine suspended solids (see discussion above).
- Generally easy to maintain (with some key exceptions), as the ACT Government's stormwater maintenance contractor is well equipped for these systems, however they are becoming increasingly expensive to maintain, as tipping fees have recently increased for the material removed. TAMS reported that they used to dispose of the sediments removed from GPTs to a local recycler for $25/tonne, however the EPA has recently ruled that the material needs to be disposed to an approved landfill as general solid waste, at $189/tonne. This has substantially increased cleanout costs.

- Causing some issues in terms of local amenity – particularly where residential or other development has occurred in close proximity to GPTs or where they are located in high-use open space. These GPTs are unattractive and can be smelly. Maintenance methods also rely on using large drying areas to dewater pollutants removed from the GPT.

Proprietary GPTs are:

- Typically, not being maintained frequently enough to perform as they should. In the worst cases, this means that they have completely failed. Others may work for a few storm events after a clean-out, and then are completely full and operating in bypass mode.
- Often difficult for the ACT Government's stormwater contractor to maintain, as they are not well equipped to deal with the range of systems being installed, and have not had the opportunity for adequate training. Some GPTs also have specific access or other issues.

Why are these performance issues occurring?

Again, it is easiest to understand performance issues in the context of the Major/Minor and proprietary GPTs.

Major/Minor GPTs have been designed for the ACT and used successfully for many years. However, their key issues come down to the designs themselves. These GPTs are generally easy to maintain and suit the stormwater management paradigm of the 1970s and '80s but the following issues have emerged more recently:

- The strategy for location of GPTs at the downstream end of large catchments is no longer entirely appropriate in the context of current stormwater treatment objectives, which require a more substantial treatment train and generally means that stormwater treatment commences closer to the source.
- As these GPTs are located online, they are prone to larger events washing out the pollutants trapped in smaller events.
- The trash rack is simple and robust, but not particularly effective for capturing smaller floating material. Many of the trash racks also clog easily, so they overtop quickly. Once overtopped, the trash rack is ineffective for trapping floating material.
- The designs do not take into account the potential problems associated with anaerobic decomposition of organic matter in a permanent wet sump.
- The designs are not appropriate in close proximity to development or high-use open space.

Proprietary GPTs have a range of more complex issues which impact on their performance, including:

- The ACT's design standards do not provide a clear pathway to select or size an appropriate proprietary GPT, so there is a lack of guidance to developers, DA assessment or asset acceptance staff (however we understand that these standards are currently being reviewed).
- The preference of developers is generally for proprietary GPTs which suggest (on paper) a high pollutant removal performance. This could help to demonstrate compliance with the WSUD Code targets. Developers also typically prefer underground units which are out of sight. However, maintenance is not a significant consideration in their selection process, as they will only be responsible for maintenance for a short period prior to asset handover.
- GPTs are often installed before construction is complete in the upstream catchment. While the Major/Minor systems are relatively robust in this situation, some proprietary GPTs are easily damaged by construction-stage pollutant loads. An example was mentioned in interviews where cement waste washed into an underground GPT and solidified. Large debris can also damage some GPTs.
- Asset handover processes are failing to effectively identify GPTs and hand them over to maintenance staff (let alone providing appropriate documentation or training). Maintenance staff report that they normally find out about new GPTs when out in the field or when they receive an odour complaint. This means that when new GPTs are cleaned for the first time, they are often in a state of considerable disrepair.

- While the expectation in the ACT is that GPTs will be cleaned out biannually, many proprietary GPTs require much more frequent maintenance in order to function effectively. Under a biannual cleaning regime, some proprietary GPTs are prone to complete failure and irreversible damage; others may simply perform well below expectations.

Opportunities to improve performance

A key issue with GPTs is the maintenance burden, and the balance between pollutant removal performance and maintenance. Measures to improve pollutant trapping efficiency are pointless unless there is capacity to clean out the additional material which is trapped.

Therefore, our review has focused to date on the following types of opportunities:

- **"Quick fixes"** which could improve the ease of maintenance without substantially changing the pollutant removal performance (e.g., removing the basket from the Wentworth Avenue CDS unit and installing new covers at De Little Circuit, which can easily be removed by hand).
- Minor **rectification** works which could improve the pollutant removal performance without substantially changing the maintenance burden (e.g., increasing the length or area of a trash rack so that it blocks less easily and traps more pollutants).
- More substantial **redesign** options where there are opportunities to substantially improve performance or ease of maintenance (e.g., installing a high flow bypass or separating a system into multiple cells).
- At selected sites, older GPTs could be considered for **removal**, if replaced by GPTs further upstream in the catchment.

Some broader actions could also improve the performance of new GPTs, including:

- in greenfield areas, most GPTs should be offline during the construction stage
- improving asset handover processes including O&M manuals and training (where required)
- considering the use of telemetry to monitor major GPTs and identify when they need cleaning
- revisiting the possibility of recycling material removed from GPTs in order to reduce disposal costs and free up budget for additional maintenance (we understand that a trial has been proposed).