Prepared for Riverview Projects (ACT) Pty Ltd
19 September 2014

WEST BELCONNEN

A Water Sensitive Community

Water Sensitive Urban Design Report

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"The development parameters, (dwelling numbers, stages, etc.) referred to in this report may vary over time. The figures contained herein are estimates; they represent a good approximation of likely development outcomes to a sufficient level of accuracy for the purposes of this report."

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EXECUTIVE SUMMARY

Executive Summary

The West Belconnen project, straddling the Australian Capital Territory (ACT) and New South Wales (NSW) borders, is proposed for rezoning and development by the ACT Land Development Agency (LDA) and various landowners in NSW. Riverview Projects (ACT) Pty Limited is managing the project on behalf of all the ACT LDA and the NSW landowners. The project seeks to apply best contemporary and sustainable planning and design practices to create a sustainable, community-orientated settlement as an extension to the town of Belconnen.

This executive summary of the development of a water sensitive community outlines how Water Sensitive Urban Design (WSUD) principles can be integrated into the future community to achieve the overarching sustainable development objectives for West Belconnen. It describes:

- The adopted water management and WSUD “vision” for the project
- The details of three representative water management arrangements. Three scenarios were developed to enable a preliminary benefit and cost comparison among them, with a view to informing future decisions on the optimal strategy and infrastructure arrangement
- A discussion on the key features of the WSUD strategy, how they evolved, and how they respond to the various site and environment and constraints
- A comparison of environmental performance and infrastructure costs of the described water management scenarios, with a statement of the key findings from the work undertaken to date
- The recommended next steps to further refine the WSUD strategy.

“A Water Sensitive Community”: Vision and Principles

The sustainability vision adopted for the West Belconnen ‘21st Century Garden Suburb’ development has been characterised as “creating a sustainable community of international significance in the nation’s capital.” To determine how this vision could be applied to the management of the urban water cycle, a review was carried out of the site context (including the hydrology and topography, sensitive ecological values, environmental water needs, opportunities for water recycling, *etc.*), international practices and innovations in integrated urban water cycle management, and the relevant local planning and design codes (in particular the ACT’s *Water Sensitive Urban Design General Code*[1] [the ACT WSUD Code]). Further, the Green Building Council of Australia’s (GBCA’s) *Green Star - Communities PILOT* rating tool has been adopted to guide and evaluate the delivery of sustainable design measures overall at the site. The rating tool contains objectives and scoring criteria that relate to potable water demands, stormwater quality and flow management, water recycling, and climate management.

The master plan of a water sensitive community at West Belconnen has been founded on the following principles:

1) Working toward a ‘Water Neutral Community’ - Minimising potable water demand and wastewater discharges into the adjacent Murrumbidgee River, and protecting the ephemeral creek lines from adverse impacts, ideally by mimicking predevelopment hydrology of the site, or exploring alternatives achieving similar outcomes
2) Understanding that ‘The City is your Catchment’ – Explore harvesting and using the stormwater as an alternative water source (*e.g.* as a ‘third pipe’ for irrigation and non-potable domestic uses), how deploying sensible onsite rainwater capture and use on blocks can reduce potable water demands, and whether the capture and reuse can prevent loads of contaminants entering waterways
3) ‘Make the Landscape Work’ - Using functional landscapes for stormwater treatment and maintaining soil and vegetation health and contribute to more liveable urban environments. In particular, the landscape has to work to protect the health and condition of the adjacent Murrumbidgee River corridor
4) ‘Produce the Food You Consume’ – Explore opportunities to use stormwater and/or wastewater to support urban planting and food production, noting that local food production is a component of a sustainable community and one of the beneficial uses of harvested stormwater
5) ‘Make the Cities Work for Waterways’ – Develop a new model for urbanism, reduce and manage pollution to waterways and repair riparian corridors. Creating new communities does not need to come at the cost of our environment.

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[1] It is acknowledged that the ACT WSUD Code is currently under review; the adopted water flow and quality management objectives for this study refer to the Code that was current at the time of this report.

Development scenarios

Balancing performance and cost

The pursuit of a sustainable and water sensitive community needs to be undertaken with cost and delivery implications in mind. As such, the initial approach had been to generate two water cycle management scenarios and then to compare the infrastructure and cost requirements against the environmental and liveability benefits. The first 'base' scenario was developed to meet basic regulated water quality and flow management requirements, and the second was designed as an 'aspirational' case with ambitious objectives in mind, borne through an international WSUD practice review and the sustainability vision for the development.

However, it is also recognised that the ultimately preferred arrangement may sit somewhere in between these two initial scenarios. A number of possible interim arrangements can exist, each with different characteristics and balances between benefits and costs. As such a third 'intermediary' arrangement was generated and assessed. Details are provided below.

Scenario 1: 'Base'

The first scenario relates to achieving the fundamental water flow and quality management requirements at the site to satisfy regulatory codes and other guidelines. The 'base' water quality and flow objectives were developed based on consideration of regulated water management objectives, and in particular the ACT WSUD Code (which is effectively a reflection of good practice in NSW as well). The other key influence on the development of the water management scenarios has been the balancing of the site topography, hydrology and context with the Murrumbidgee River corridor to meet water quality and management objectives.

The main features of the 'base' water infrastructure arrangements include:

- Roof water is captured in rainwater tanks, and is used for domestic non-potable demands such as toilet flushing, laundry and garden irrigation. Any overflow drains to the streetscape to passively water the verge
- Rain that falls on the ground is captured by the minor stormwater drainage network and directed to constructed stormwater wetlands for treatment. Peak flows are attenuated to pre-development flows and additional stormwater derived from the increased post-development runoff from the site flows down the existing drainage gullies to the adjacent river and creek.

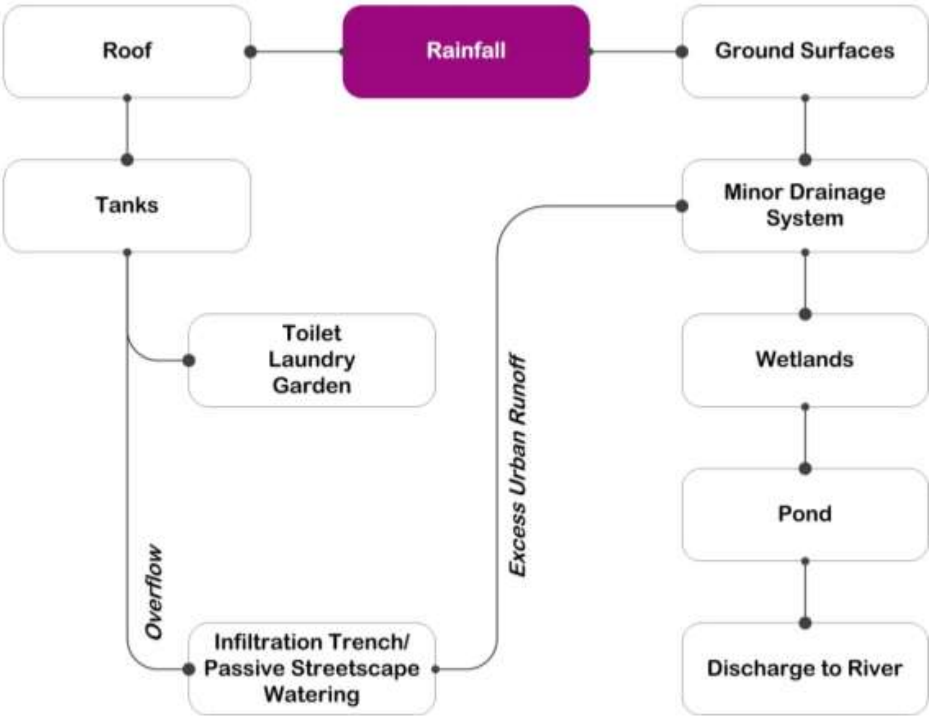

Figure A Scenario 1 'Base' water cycle

Scenario 2: 'Aspirational'

This scenario reflects achieving more aspirational objectives for water quality and flow management primarily based on the review of international approaches to water management and to achieve design outcomes driven by the *Green Star - Communities'* water-related criteria. The 'aspirational' arrangements are fundamentally the same as for the 'base' scenario except for the addition of the following:

- Stormwater is stored in ponds. Water from the ponds is fed to header tanks where it is treated and distributed through a 'third pipe' supply network to homes. The third pipe supplies domestic non-potable demands such as toilet, laundry, and garden irrigation. The third pipe can also supply water for irrigation of all public open space, and offsite agricultural applications and the nearby golf course (and/or other offsite users). Due to the higher harvesting and use of the stormwater, overflows to the receiving river and creek environments are rarer and smaller in volume as compared to the 'base' scenario
- Roof water is additionally used to supply hot water demands at each household which alleviates the demands on the potable water system further.

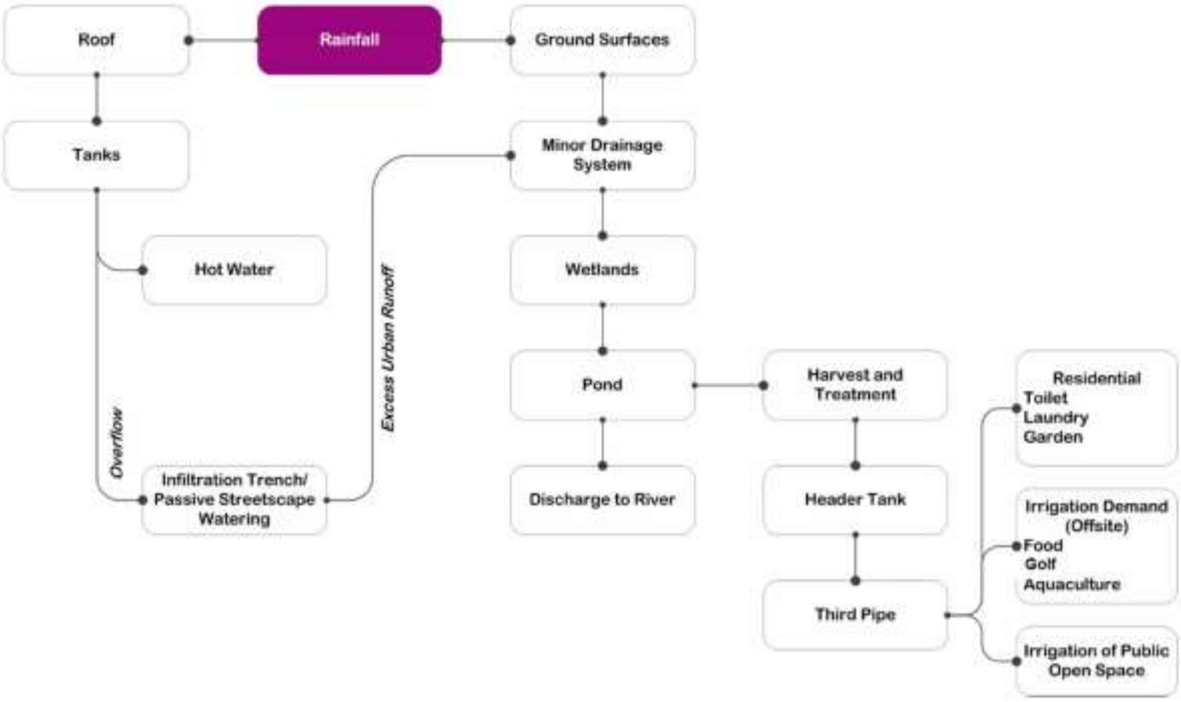

Figure B Scenario 2 'Aspirational' water cycle

Scenario 3: 'Intermediary'

The features that underpin the 'intermediary' scenario are:

- Retaining the wetlands, ponds and bioretention system layouts as per the other scenarios to achieve the mandated water quality and flow management requirements
- Elimination of the 'third pipe' network to households (as was described in Scenario 2) and a reduced reliance on stormwater harvesting to enable smaller, decentralised harvesting and public open space irrigation systems (primarily to manage the site water balance and control flows), noting there are several examples of similar systems in place in the ACT and NSW.

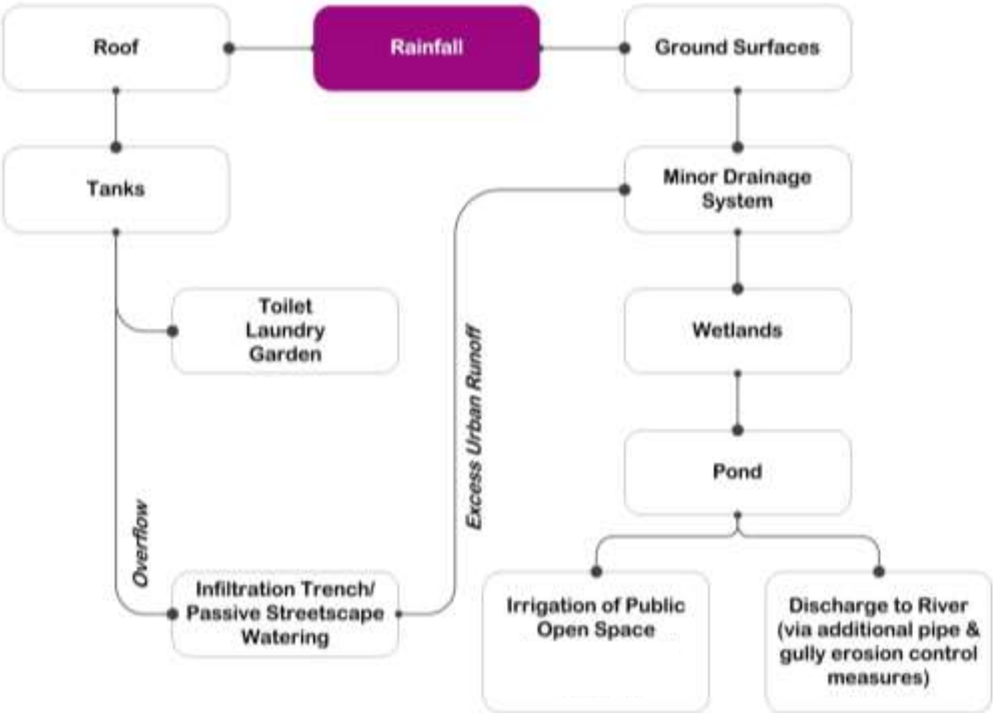

Figure C Scenario 3 'Intermediary' water cycle

Evolution and features of the master plan

This section summarises the rationale underpinning the main features of the WSUD master plan layouts and details for the various scenarios.

All scenarios

Accommodating site constraints. Hydrology, water quality and water balance modelling was undertaken to refine the location, sizing and other requirements of the infrastructure, with the following in mind:

- Avoidance of the various site constraints (*i.e*. Pink-Tailed Worm Lizard habitat, avoiding or minimising land-take of developable land, power infrastructure, heritage trees and other items)
- Consolidation of the numbers of ponds, wetlands, *etc*. as far as practical to minimise the maintenance and other ongoing asset management requirements, et still meet water quality management requirements
- Minimising the infrastructure requirements and delivery cost (*e.g.* for Scenario 2 this included adopting a centralised treatment and distribution point for harvested stormwater with a high relative level to avoid pumping infrastructure)
- Accommodating the overall structure plan layout as it was being developed in parallel by other consultant teams.

A series of wetlands, ponds and bioretention systems. The landscape contains many small gullies and ephemeral creek lines that drain to the adjacent Murrumbidgee River and Ginninderra Creek corridors. There are 27 major discharge points to the nearby river and creeks. Working with these to maintain the natural topography means that all scenarios depend upon a high number of 'decentralised' ponds, wetlands and bioretention systems to provide the required residence times and treatments to meet flow and quality requirements. The average catchment area to each major measure is approximately 30 hectares, which is comparable to other similar developments in the ACT.

Considering maintenance and operating costs. A system of decentralised WSUD measures, predominantly involving ponds and wetlands, was preferred to other approaches such as extensive rain gardens in the streetscape or biorention basins which, while potentially more effective, also attract greater maintenance and operational requirements. Equally, stormwater harvesting facilities have been consolidated and centralised where possible. There might be a limited potential for some of the identified infrastructure to be further consolidated as the master planning for the site progresses and is refined; however these have been consolidated as far as practical for the purposes of the master plan.

Use of rainwater tanks. The ACT WSUD Code, in its current form, requires the inclusion of rainwater tanks on all new developments. Tanks were accommodated and options were explored for the appropriate types of uses of rainwater, the impacts they have on the water cycle, and their part in meeting water management objectives under the scenarios. Generally, the greater use of rainwater (and stormwater) harvesting contributes to reduced pollutant loads entering the receiving waters via site runoff, as discussed further later.

Scenario 3

Addressing uncertainties of Scenarios 1 and 2. The first two described scenarios are technically feasible and meet (and, in the case of Scenario 2, exceed) the water flow and quality management requirements set out in the WSUD Code. However there are uncertainties about the feasibility of either arrangement on other fronts that still need to be resolved. The primary ones are that:

- A critical environmental objective for the project was protecting the drainage gullies along the escarpment of the Murrumbidgee River corridor. The 'aspirational' Scenario 2 strategy is effectively a water management system that would have very limited impact on the hydrological regimes of all nearby waterways including the drainage gullies, the Murrumbidgee River and Ginninderra Creek. As they stand only Scenario 2 achieved the sort of stormwater flow mitigation that would contribute to protecting the ephemeral waterways and drainage lines across the site. In the absence of adopting Scenario 2 additional stabilisation or scour protection work may be warranted, and
- The financial and operating viability of the stormwater harvesting scheme in Scenario 2 requires further testing. Presently there is no obvious owner and operator of a stormwater harvesting scheme at the described scale, and no precedent in the ACT of providing such a scheme for domestic water uses which would require agreements with relevant resources, health and utility regulators.

To provide confidence that a water management arrangement can be defined that would address these issues, the hypothetical 'intermediary' Scenario 3, with decentralised smaller scale stormwater harvesting schemes (similar to those already in place in the ACT) has been preliminarily tested and described, including the provision for river corridor protection measures. Regarding the scour and erosion control of the gullies under this scenario, note:

- Given the limited ecological values, flat slope and proximity of the proposed WSUD (wetlands, ponds, *etc.*) measures to Ginninderra Creek it will be feasible to simply include stabilised and adequately designed waterways to drain the northern part of the site to Ginninderra Creek.
- For the Murrumbidgee River interface, a more delicate approach could be taken. The proposed additional gully protection measures could include:
  - A proposed series of small size stormwater drainage pipe along the urban edge of the Murrumbidgee Corridor to transfer the small flows corresponding the discharge of the small frequent storm and extended attenuation volume, and by doing so divert water away from more sensitive and erosion prone gullies to more stable, less sensitive ones where erosion and scour protection can be reinforced
  - Co-locating as much as possible some additional stormwater drainage mains with a proposed (and only potential) sewer alignment largely following the urban side of the river corridor boundary. This would reduce construction cost and simplify the access and maintenance.

Scenarios 2 and 3

Stormwater harvesting to contribute to meeting flow and quality management goals, as well as reducing dependence on the potable system. It is important to note that the availability of surplus stormwater and the need to manage flows leaving the development site was the driver for exploring an opportunity to use it for irrigation and domestic non-potable purposes, rather than a desire to limit and replace potable water demands.

The post-development increase in imperviousness together with the topographical features create large volumes of surface water and potentially large flows during rainfall events that need to be managed in a way that meets the WSUD Code requirements and the conservation needs of the river corridor (especially scour and erosion management).

As such Scenario 2 explored the creation of a large-scale stormwater harvesting and use scheme, with users and demand points created so as to manage peak flows from the site with a view to accommodating the neighbouring creek and river corridors. This included identifying the public open spaces that would benefit from the irrigation water and determining the water balance to match the demands. For Scenario 2, the stormwater reuse potential was extended to include provision of a third pipe to residences for non-potable water needs. An additional benefit identified during later work of the large-scale harvesting is that it provides greater reductions in nutrient, solids and other contaminants entering the river, as a consequence of the reduced runoff volumes.

However, such a stormwater harvesting arrangement as per Scenario 2 has no precedent in the ACT or NSW and its financial feasibility is unknown. Another option, as per Scenario 3, would be to reduce the stormwater harvesting arrangements to a scale that is more typical in ACT and NSW and pipe the resultant excess flows from the site down to the river; however this would also have a cost associated with it, would impact on the objective to minimise construction and visual impacts on the corridor, and neglects the opportunity of further minimising reliance on the potable water network through beneficial reuse.

Providing an adequate level of reliability of storm water supply to the identified potential users will also be necessary, and this can be achieved under either of the scenarios that include stormwater harvesting systems. Note that for either scenario, a potable water back-up would need to be provided.

***Stormwater transfer infrastructure**.* For Scenario 2 the use of ‘tank farms’ and a connected pipe grid was necessary to distribute and balance the stormwater resource among the major large ponds. For Scenario 3, decentralised, pressurised (so no need for pumps) small scale systems would be preferred to enable localised irrigation and limit the operational maintenance, management and costs.

Scenario 2

***Stormwater treatment infrastructure**. S*hould the option of stormwater harvesting and delivery to homes through a ‘third pipe’ system be adopted, it will require centralised filtration and disinfection, as well as a robust water quality monitoring and management plan, to satisfy health risk management requirements.

The role and rationale for alternative water sources

Identifying opportunities and roles for the deployment of alternative water resources (stormwater, treated wastewater, *etc.*) was a key component of the study scope. Decisions to implement alternative water and water reuse schemes need to be based on a well-rounded economic basis, *i.e.* considering and providing for a net social, financial and environmental benefit, and not just on the rationale to reduce reliance on the primary potable water resource. This is particularly so in the ACT where there has been a recent significant investment in potable water supply security infrastructure.

The nearby Lower Molonglo Water Quality Control Centre (LMWQCC) was identified early in the study as a potential supplier of treated wastewater effluent for non-potable water uses (as there are already similar schemes in place). A stormwater harvesting scheme has been preferred in the development of water management scenarios. The rationale was based upon:

- Determining (through modelling) early that the surplus stormwater runoff being generated at the site would require novel management and disposal solutions, and there was an opportunity associated with this for beneficial reuse
- For either Scenario 2 or 3, it is likely that either stormwater or LMWQCC effluent reuse would require similar additional infrastructure to distribute the water and to meet the health risk management requirements of the *Australian Water Recycling Guidelines*
- If the LMWQCC effluent were used instead of the stormwater for irrigation, *etc.*, the stormwater management infrastructure would need to include additional high-flow pipelines running down the river corridor and/or other scour protection measures in any case
- The LMWQCC effluent currently contributes to controlled environmental flows in the Murrumbidgee River for downstream irrigators. Using it on the development site would have other water balance accounting implications for the ACT under the Sustainable Diversion Limits set out in the *Murray-Darling Basin Plan*.

Another ‘alternative’ water source that features heavily in the master plan is roof water captured for domestic, non-potable uses. Rain water tanks are a mandatory requirement in the ACT, correspond to current good practice and have been included as a feature on all new residences, noting:

- Under the ‘base’ Scenario 1 rainwater is used for domestic irrigation, toilet flushing and laundry demands
- Under the ‘aspirational’ Scenario 2 these domestic non-potable demands can be reasonably met by the stormwater harvesting scheme, freeing rainwater to cater to another demand: hot water. This further contributes to limiting the stormwater and contaminant generation from the development site.

Ginninderra Creek and the Murrumbidgee River

Managing impacts on the corridors and receiving environments

Under any of the scenarios there will be an increase in the long-term runoff generated from the site as compared to the present situation, noting that peak flows would be managed in line with flood management requirements and the ACT WSUD Code. Providing that the conveyance of the additional stormwater flows to Ginninderra Creek and the Murrumbidgee River is done in an environmentally sensitive way the creeks and rivers themselves would experience a negligible impact from the increased flow generated from the project[2] – indeed the small increase in overall flows may be beneficial to river water users downstream.

Murrumbidgee River corridor interventions to protect gullies and habitats for the various scenarios

The large-scale stormwater harvesting scheme plays a pivotal role in managing flow rates from the development site to levels that could be accommodated by the Murrumbidgee River corridor with minimal intervention or additional infrastructure. Maintaining the corridor in its present state is an aim of the development. To provide a comparison of the implications of the various scenarios in terms of the impact on the corridor, note that:

- Scenario 1 (‘base’) could require water collection, major pipes running down the corridor and velocity/shear stress control infrastructure to minimise erosion and scour on the gullies
- Scenario 2 (aspirational’) would require minimal, if any, intervention in the corridor
- Scenario 3 (‘intermediary’) could require additional flow collection, piping along the top edge of the corridor and flow diversion to the gullies more able to accommodate additional flow rates and stresses, and revegetation or armouring of many other gullies.

Ginninderra Creek provides an alternate water disposal option for the ‘aspirational’ Scenario 2

The extent of the demands for the harvested stormwater under this scenario went beyond the site itself and identified that offsite users, such as nearby golf courses, *etc.* were necessary to balance the site flows in such a way to minimise the risk of scour damage to the sensitive gullies draining to the Murrumbidgee River. However, it has not been tested whether such customers would provide the necessary market for the stormwater. As a back-up, it was tested whether the ‘excess’ stormwater would be able to be conveyed to Ginninderra Creek and drained to the river via that route, and in an environmentally sensitive way. Effectively the creek would cope and in a manner that would enable Scenario 2 to still have the advantage of not requiring the gully protection infrastructure and measures that may be necessary under the other scenarios, and so there is an alternative water management measure in the event that the offsite demands do not eventuate.

Outcomes

Each of the scenarios developed comply with the basic requirements of the ACT WSUD Code and with other water and environmental management needs of ACT, NSW and the Commonwealth as they relate to water quality and flow management. To differentiate the scenarios, there are two primary measures that have been developed through this study:

- Environmental (water flow, quality and Murrumbidgee River corridor impacts) performance including potential contribution to the *Green Star - Communities* point scoring (and so the stated aspiration to achieve a “6-star” rating for international significance), and
- Infrastructure costs.

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[2] Noting the project area represents 2.5% of the Ginninderra Creek catchment (32,000 hectares) and 0.14% of the Murrumbidgee River catchment (1,141,000 hectares).

These outcomes can assist to make decisions about what aspects of either scenario presented may be pursued and further defined during more detailed design stages.

Environmental comparison of scenarios

A comparison of the three scenarios is tabulated below (Table A). It is important to note that while, as they are described, all scenarios meet ACT WSUD Code targets, only the Scenario 2 achieves the sort of stormwater flow mitigation that would contribute to protecting the ephemeral waterways and drainage lines across the site without significant stabilisation or scour protection work. While peak stormwater flows can be attenuated to pre-development levels in all scenarios it is the number of runoff days that would contribute to degrading and scouring the ephemeral waterways under the 'base' scenario. With an increase in runoff days of up to 20 times that of estimated pre-development, this is likely to be incompatible with the protection of the Murrumbidgee corridor. A significant reduction in number of flow days is achieved under the Scenario 2 through the WSUD measures and stormwater harvesting. This would support the long term stabilisation and protection of the ephemeral waterways down the escarpment to the Murrumbidgee River without the need for additional intervention. Otherwise, additional interventions including revegetation and/or localised stabilisation through ecological or civil engineering may be required to satisfy environmental management requirements of the site.

Preliminary opinion of cost

Preliminary costing for the infrastructure necessary to deliver Scenarios 1 and 2 is provided below (Table B).

Table A Environmental performance comparison among three water management scenarios

Outcome	**'Base'** **Scenario 1**	**'Aspirational'** **Scenario 2**	**'Intermediary'** **Scenario 3**
Stormwater volume reduction	40.2%	55.7%	46.2%
Runoff days[3] (range across various sub-catchments)	55-120 days	20-90 days	20 -105+ days
Peak flow attenuation for 1 in 2 and 1 in 100 year flows	yes	yes	Yes
Reduction in Gross Pollutants Loads emanating from site	99.8%	99.8%	99.8%
Reduction in Suspended Solids Loads emanating from site	88.9%	90.6%	89.4%
Reduction in Total Phosphorus Loads emanating from site	71.3%	78.1%	73.6%
Reduction in Total Nitrogen Loads emanating from site	65.3%	72.7%	68.4%
Potable Water Substitution	27%[2]	36%	~30%
Sewer discharge reduction	0%	0%	0%
Scour potential on Murrumbidgee River drainage gullies (relative amongst the three scenarios)	Higher – could require extensive collection and piping of excess flows down the corridor	Lower – excess flows managed through onsite WSUD and stormwater harvesting measures	Moderate – could require corridor protection and flow intervention measures
Green Star Communities points[1]	★★☆☆☆ (1.5)	★★★★☆ (3.75)	★★☆☆☆ (1.75)

Table notes: 1. Indicative 'self-assessment' (out of 5) against Env-7 and Env-8 credits only of the rating Green Star rating criteria; 2. Rain water tanks are providing the stated potable water substitution; 3. Defined here as any day on which flows from a sub-catchment are in excess of base flow.

Table B **Infrastructure delivery cost comparison between three water management scenarios**

Infrastructure component	**'Base'** **Scenario 1**	**'Aspirational'** **Scenario 2**	**'Intermediary'** **Scenario 3**
Basins, wetlands and ponds[2]	$9.7M	$9.7M	$9.7M
Stormwater harvesting rising mains and pumps	-	$8.6M	$6.8M
Stormwater harvesting tanks	-	$8.0M	-
Stormwater treatment plant	-	$17.0M	-
Non potable reticulation network (third pipe network)	-	$48.4M	-
Total infrastructure[1]	**$9.7M**	**$91.6M**	**$16.5M**
Preliminaries (15%)	**$1.5M**	**$13.7M**	**$2.5M**
Contingencies (30%)	**$3.4M**	**$31.6M**	**$5.7M**
Total Preliminary Estimate:	**$14.6M**	**$137M**	**$24.7M**

Table notes: 1. Excludes hydraulic structures: inlet/outlet/dam reinforcement and spillways and river corridor protection requirements that differ among the scenarios– these are being designed and costed by others. In comparing the scenario cost estimates, it is important to acknowledge that each scenario may have different major stormwater trunk and transfer requirements that may alter the relative costs of the overall water management strategies; 2. Assumes use of site material only – if clay lining requires imported material, an additional $8.5m may be required

Key outcome

Upon reviewing the water management scenarios in this report, note that each arrangement meets the water quality and flow management requirements of the future development particularly as outlined in the ACT WSUD Code, with various levels of environmental performance beyond that baseline and with different associated costs. Investigations to determine the optimal WSUD solution are ongoing and will be informed by a 'triple bottom line' assessment of community and stakeholder environmental, social and financial impacts and benefits, as described below.

Next steps

A 'triple bottom line' assessment

A detailed benefit-cost assessment to establish the preferred arrangements for the water management regime and, in particular (if it is part of the preferred arrangement) the possible business/governance arrangements of a stormwater harvesting scheme (especially considering the inter-jurisdictional context) is necessary. Though the Scenario 2 establishment costs are much greater and have higher recurrent operational and maintenance costs, it remains to be further tested whether and to what extent these may be offset through improved environmental outcomes, avoided infrastructure and/or the sale of the stormwater for domestic and public space uses, as well as to gauge the community's willingness to pay for the resource. Ultimately, a triple bottom line (TBL) assessment should be undertaken on all scenarios to determine where on the spectrum of options between the identified 'base' and 'aspirational' cases the preferred solution would be.

Relating to stormwater harvesting

Importantly the potential role of alternative water sources requires further testing. Presently there is no obvious owner and operator of a stormwater harvesting scheme, and no precedent in the ACT of providing such a scheme for domestic water uses. As part of the 'whole water system and community' benefit-cost assessment described above, it would be necessary to determine the viability and models for establishing a stormwater harvesting, treatment and delivery entity. The identification of the owner/operator is currently a major challenge that needs to be overcome. Beyond the regulatory issues, the business case needs to be progressed further as well.

Additionally, the proposal to use rainwater for hot water and to provide stormwater via a 'third pipe' into households will require the development of the appropriate water quality monitoring and control mechanisms and approval by relevant health authorities in the ACT and NSW. The preliminary work carried out identifies a possible treatment train that would satisfy these requirements and implementing such a scheme would need to be in accordance with *Australian Guidelines for Water Recycling* including adherence to an approved water quality monitoring, validation and verification plan.

Steps for progressing to a preferred arrangement and detailed design

A continued focus on consultation with relevant organisations and bodies will be required to further develop the WSUD components of the master plan. The following is recommended:

1) Undertake a detailed benefit-cost assessment to establish arrangements for the implementation of the 'aspirational' water management scenario and the possible business/governance arrangements of a stormwater harvesting scheme (especially considering the inter-jurisdictional context)

2) In pursuing the 'aspirational' scenario further engagement will be required with relevant health, water and infrastructure regulators in NSW and ACT to develop the approval requirements that would have to be met for the project, particularly around the stormwater harvesting scheme and the 'rain to hot' water proposal.

3) Liaison with the asset management entities (most likely Territory and Municipal Services and/or ACTEW Water in ACT and Yass Valley Shire Council in NSW or a private sector water utility) that could inherit and maintain the stormwater management and WSUD infrastructure is required to establish asset design and acceptance criteria. Additionally, the ongoing funding for maintenance and operation of the WSUD measures including ponds, wetlands, bioretention systems and the stormwater harvesting infrastructure will be critical to the ongoing performance of the proposed treatment train. Failure to undertake the adequate maintenance of the assets could result in sub-optimal performance and outcomes over time. It will be important to explore how to ensure the necessary regime of maintenance by the key asset management entities can be made feasible, as well as what roles others (*e.g.* an environment/conservation trust, the local catchment group, or a dedicated not-for-profit community group) may play

4) A part of the former landfill site was identified as a potential location for the tank farms and potential stormwater treatment plant described in Scenario 2. The geotechnical suitability of the site needs to be confirmed for the purpose of accommodating the locally heavy load and how geotechnical improvements might support such a proposal, if required

5) The overall model developed to test stormwater quality, harvesting and flow management is based on a structure plan that was current at February 2014. An updated structure plan has been developed since. The strategic findings and figures reported in this document are still relevant for the purpose of land planning and strategic infrastructure planning. It will be important to revise the models prior to progressing to the next phase of water sensitive urban design

6) As part of the stormwater harvesting plan development, estimates of demands for potential uses including public open space irrigation, urban food production, *etc.* were made. As planning for such land uses progresses, it will be necessary to verify and refine the assumptions and test the impacts of any changes on the water system design parameters

7) The water quality management outcomes are not spread evenly across the site. Modelling suggests that a small number (4) of sub-catchments near the river corridor for which the topography or proposed land use pose particular challenges may have runoff water of poorer quality than other parts of the site. The expected total treatment train in these sub-catchments will require additional streetscape rain garden and bioretention systems in order to further improve the water quality. It is not yet possible to develop such 'sub-catchment specific' treatment trains as the urban design and planning has not progressed enough. This needs attention as the urban design and planning progresses

8) Integrating with the civil infrastructure planning and design is necessary, including integration of:
   - Non-potable and potable infrastructure and reticulation networks
   - Inlet and outlet structures to the basins, including locations of treatment of the points of discharge from basins
   - Earthworks modelling and treatment of the embankments for the ponds, wetlands, *etc.*

INTRODUCTION

1.0 Introduction

1.1 The West Belconnen development

The proposal for the West Belconnen area, straddling the Australian Capital Territory (ACT) and New South Wales (NSW) borders (Figure 3), is that over the next 20 – 30 years the area will provide around 10,000 homes for up to 30,000 people, with new centres, jobs and community facilities. Over the next 10 – 15 years, approximately 4,500 new homes will be developed on the ACT side of the border, with development of the NSW land to follow.

Riverview Projects (ACT) Pty Ltd is the project manager for the planning of West Belconnen, acting on behalf of the ACT Government with respect to the ACT land, and on behalf of the landowners within the NSW section. There has been a visionary commitment by Riverview and the ACT Land Development Agency (LDA) to explore and implement integrated and innovative solutions to develop a truly sustainable community. The West Belconnen development project seeks to apply best contemporary, sustainable planning and design practices to create a community-orientated “21st Century garden suburb”.

1.2 The West Belconnen sustainability vision

The sustainability vision encompassed by Riverview for the West Belconnen development has been characterised as “creating a sustainable community of international significance in the nation’s capital.”

The Riverview has a vision of inspiring sustainable living, development practice and awareness to achieve a high quality of life for the people living in Belconnen. The proposed community development will strive to achieve internationally leading practice in sustainable design, construction and long-term liveability.

This commitment and fundamental objective of the project is encapsulated in a Sustainability Vision and Sustainability Charter that all team members adhere to. The Sustainability Charter is provided in Appendix .

The principles underpinning the development are to:

- Be sustainable over time, socially, economically and ecologically (with a low and reducing ecological footprint)
- Respond to the local and global environment
- Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms
- Be cost effective, replicable and measureable
- Act as a new model that others can follow.

Figure 1 **The Riverview sustainability definition**

1.3 Sustainable urban water management

1.3.1 Integrated water cycle management

This project will be underpinned by an integrated water cycle management (IWCM) approach. IWCM considers all water sources together to plan and manage holistic water usage solutions. It seeks to associate water supply, waste water and stormwater services in an integrated way to better utilise the available water resources. IWCM is modern practice and it is aimed at creating a water management strategy for the long-term. An IWCM approach is required to match the most appropriate sources of water with various demands both at a household and public realm level. The successful delivery of IWCM must consider environmental, social, technical and economic factors.

In a paper by the National Water Commission (NWC), the Australian Government committed to a review of "institutional and regulatory models for achieving integrated urban water cycle management and to develop guidelines in this area" (NWC, 2007). Given Australia's limited water resources, there is an emphasis on sustainability and integration in urban development. Fundamentally, the objectives of IWCM are to minimise the impacts of urban development on the existing environment. Water Sensitive Urban Design (WSUD) is part of the IWCM model as depicted in Figure 2.

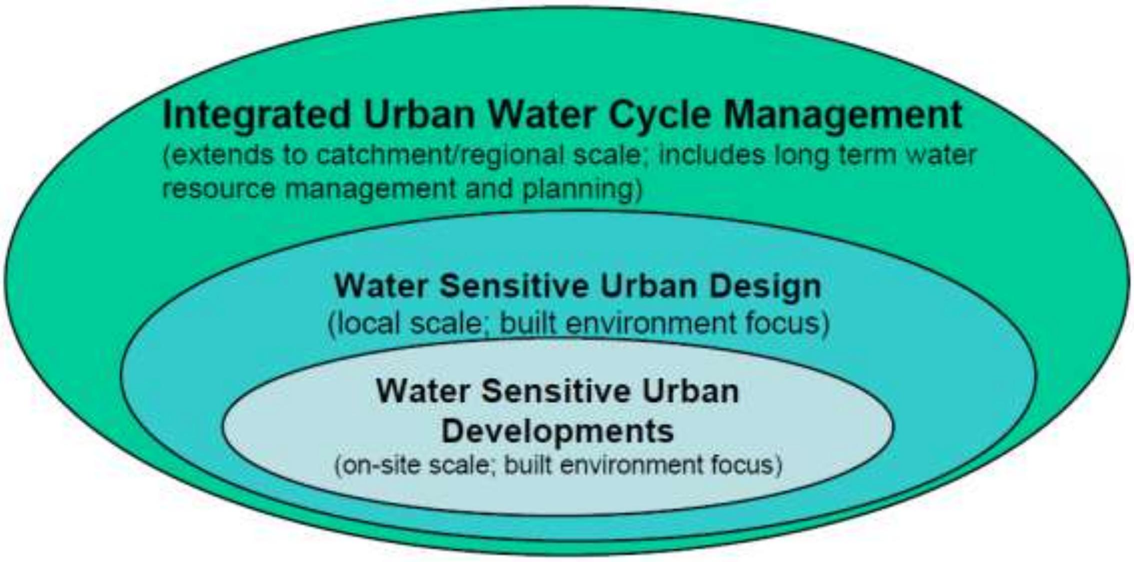

Figure 2 **Conceptual Model of urban Integrated Water Cycle Management and related concepts (source: NWC, 2007)**

1.3.2 Water sensitive urban design

Water sensitive urban design (WSUD) aims to enhance the connectivity of urban environments with the people that live in them and the values they place on water. Sustainable urban water management and WSUD can contribute to the overall sustainability vision. For West Belconnen, with the potential to achieve significant outcomes such as:

1) **Maximising the developable land, while minimising infrastructure costs.** The creation of multi-functional landscapes creates high value open space and minimises the infrastructure footprint.

2) **Supporting the sustainability vision and creating a point of difference.** The WSUD features of the development can set it apart from other local suburbs. In particular, the provision of alternative water supplies will make the suburb less susceptible to water restrictions, allowing it to be a lush landscape, which has become rarer in Canberra's dry climate, particularly during the recent droughts.

3) **The landscape providing ecosystem services to reduce the environmental footprint.** The landscape can be used to reduce environmental impacts associated with the urban runoff.

4) **A community that is aware of and appreciative of the environment that they live in.** The urban design will respect the overland flow paths of water, and the surrounding habitat creating networks of and green and blue that become part of everyday life. Riparian corridors offer a 'borrowed' landscape for community members to enjoy and that supports drainage and biodiversity functions.

5) **Creation of a distinctive community identity** with high quality public open spaces, strategic infrastructure that is well placed and aligned to make it easy to use and maintain.

1.4 Study scope

With respect to developing the total water cycle management at West Belconnen, the responsibility was shared between AECOM Australia Pty Ltd (AECOM) and a team from Brown Consulting Pty Ltd (Brown) as outlined in Table 1.

This study focused on the facets of the water cycle management at West Belconnen primarily related to WSUD and on examining water recycling and reuse opportunities. The aim of this study was to:

- Translate the project sustainability vision into practical water cycle management and waterway protection principles
- Conceptually describe the broad infrastructure requirements and opportunities to realise the sustainable water management aspirations for the development, taking into account the need to balance various technical, economic, environmental and community requirements.

Table 1 Roles and responsibilities for the development of the West Belconnen water management strategies

Elements of the water cycle / infrastructure	Responsibility
Potable water infrastructure	Brown
Sewer infrastructure	Brown
Stormwater drainage (trunk infrastructure)	Brown
Recycled water and alternate water source opportunities and infrastructure	AECOM
Integrated water cycle management	AECOM
Water sensitive urban design strategy	AECOM
Overland water quality and flow management infrastructure	AECOM

1.5 Creating an innovative master plan of a water sensitive community

The pursuit of a sustainable and water sensitive community needs to be undertaken with cost and delivery implications in mind. As such, a number of water cycle management scenarios were generated and then compared in terms of the infrastructure and cost requirements against the environmental and liveability benefits.

In striving for an internationally significant project outcome, we:

1) Established a framework to define water management scenarios that reflect current common ‘base’ practices against what can be considered as more leading edge or ‘aspirational’ practice, including the articulation of water quality and flow management objectives for the development
2) Prepared ‘base case’ and ‘aspirational’ water management strategies and established cost estimates as well as key environmental and water management performance indicators against which the merits of the scenarios could be compared
3) Actively engaged with other specialists contributing to the overall project structure plan to embed and integrate WSUD principles and also to respond to the needs and constraints of these teams as their design components evolved.

Each of the above points is elaborated on below.

1.5.1 Framing innovation and sustainability

To determine how the sustainability vision could be applied to the management of the urban water cycle, a review was carried out of the site context (including the hydrology and topography, sensitive ecological values, environmental water needs, opportunities for water recycling, *etc.*), international practices and innovations in integrated urban water cycle management, and the relevant local planning and design codes (in particular the ACT’s *Water Sensitive Urban Design Code*[3] [ACTPLA, 2009, from here on referred to as the ACT WSUD Code]). Further, the Green Building Council of Australia’s (GBCA’s) *Green Star – Communities PILOT* (GBCA, 2013) rating tool has been adopted to guide and evaluate the delivery of sustainable design measures at the site. The rating tool contains objectives and scoring criteria that relate to potable water demands, stormwater quality and flow management, water recycling, and climate management. A ‘base case’ water cycle strategy was prepared

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[3] It is acknowledged that the ACT’s WSUD Code is currently under review; the adopted water flow and quality management objectives for this study refer to the Code that was current at the time of this report.

that was based largely on meeting the ACT WSUD Code requirements, the 'aspirational' case was geared toward adopting international practices and the requirements of the *Green Star - Communities* rating credits.

1.5.2 Environmental and water management performance indicators

A set of environmental and water management performance indicators was developed to improve the transparency and clarity of the respective performance of the various scenarios that were generated. These indicators were selected to adequately depict the multiple aspects and potential impacts of urban development on the site, combining parameters relating to the hydrology, hydrological regime, water quality and pollutant loads and reflecting the requirements as specified in the *Green Star Communities* credits. The performance criteria included:

- Total annual runoff volume reduction
- Number of runoff days
- Peak flow attenuation
- Gross Pollutant load removal
- Total Suspended Solids load removal
- Total Nitrogen load removal
- Total Phosphorus load removal
- Potable water substitution

Using these performance criteria, score cards were prepared to succinctly represent and enable comparison of the environmental performance of the various scenarios. Probable opinion of cost estimates were also prepared to provide another point of comparison.

1.5.3 Integration with other disciplines and consultants

Over the course of the study collaboration with other project teams was extensive, particularly with:

- Environmental scientists on the integration of the environmental values and articulation of the water related needs and sensitive of local habitats, sensitive, endangered and protected species
- Urban planners and designers to best identify the opportune sites for WSUD elements, wetlands and ponds, to integrate the drainage and green infrastructure corridor in the urban planning for the site
- Landscape architects and urban farms consultants to elaborate and derive the most judicious way of capturing, draining, harvesting and reusing stormwater across the site; and how to best integrate with the Murrumbidgee River corridor that is adjacent to the proposed development site
- Civil engineers on the integration of stormwater and WSUD assets with other key urban infrastructure assets including roads, water and sewer networks.

1.6 This report

This report has three main parts:

- **Part One: Principles and Outcomes.** Sections 2.0 - 3.0 of this report defines the principles that underpinned the development of a water sensitive community plan for West Belconnen, how they were derived, and the outcomes that they drove. The key features and placement of the WSUD infrastructure including wetlands, bioretention basins, and alternate water source and reuse infrastructure for the 'base' and 'aspirational' scenarios are described here together with an evaluation of the environmental performance and associated potential costs of delivering the scenarios.
- **Part Two: Evolution of the Master Plan.** Sections 4.0-10.0 of this report details the technical and policy aspects, site constraints and WSUD design responses, and modelling undertaken that have influenced the evolution of the master plans presented in Part One.
- **Part Three: Progressing and Evaluating the Master Plan.** The final part of the report contains the concluding statements and the primary next steps that will be pertinent to furthering the water management strategy at West Belconnen.

Figure 3 **The West Belconnen development area**

PART ONE

Principles and Outcomes

2.0 A Water Sensitive Community

The starting point for creating a water sensitive community at West Belconnen is the firm belief that urban development does not need to be done at the expense of the viability and integrity of the local waterways and receiving waters. The research and development of modern WSUD principles and technologies over the last two decades particularly in Australia has generated a large palette of principles, tools and technologies allowing an improved integration of the water cycle in our urban communities.

The following report sections outline the underpinning principles and philosophy for WSUD and integrated water management for the future West Belconnen community.

2.1 Overarching philosophy

The overarching water sensitive community philosophy is that surface water including urban stormwater runoff, existing natural waterways, future urban waterways, water use and reuse can all be integrated to reduce the impact of the development on the environment and improve the quality, amenity value, comfort, ecological function and overall liveability of the urban community.

As such the philosophy for the water management approach for this project is aligned with the principles of a ‘water sensitive city’ as developed in the last few years in Australia (particularly through the Cooperative Research Centre for Water Sensitive Cities). This involves realising an increase in the level of services delivered by stormwater and water related assets beyond that of water supply and sanitation.

Realising a water sensitive community involves pursuing:

- Guarantee of a water supply that is safe, reliable and resilient, and fit for purpose
- Safeguard of public health through adequate sewerage and drainage, and controlled non potable supply
- Protection against the impact of major floods and the nuisance of smaller frequent floods, including consideration of the impact of climate change on rainfall patterns
- Supporting the provision of improved social and environmental amenities and contribute to more active and healthy urban forms
- Producing resource efficient infrastructure solutions that preserve natural resources and reduce the resource intensity of infrastructure provision and delivery.

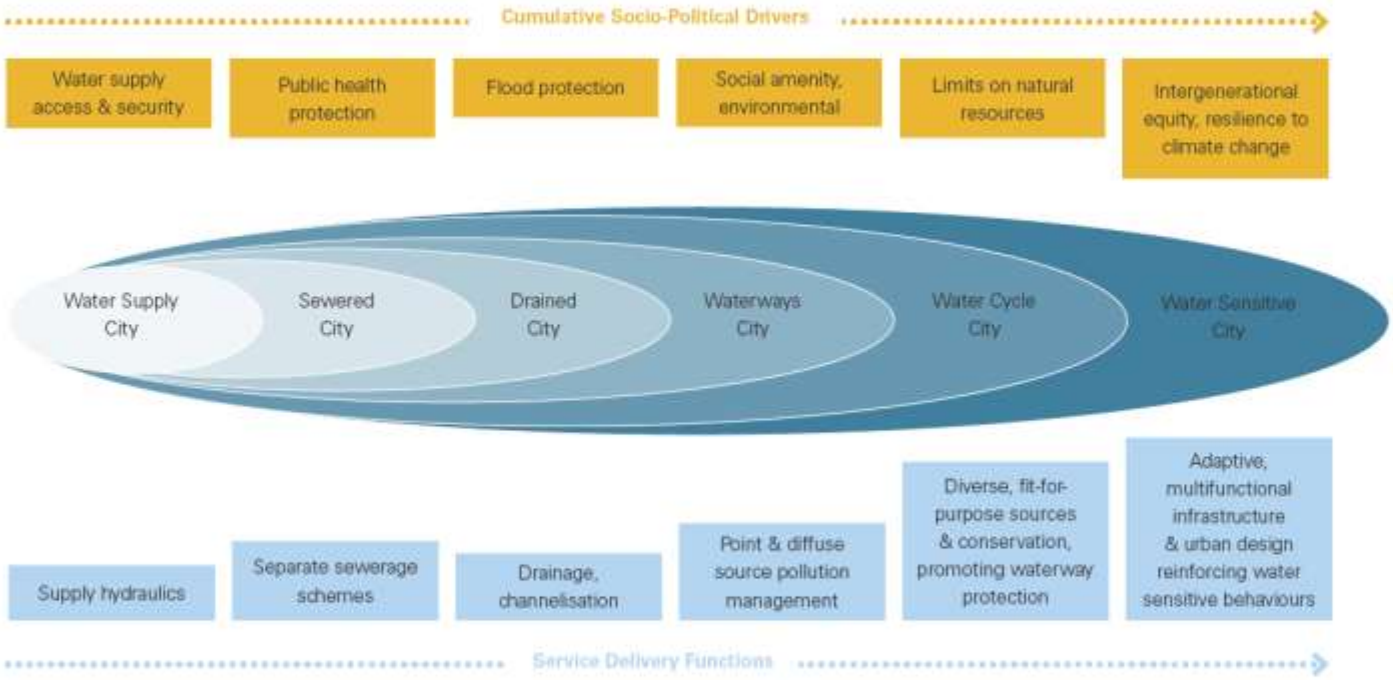


Figure 4 A water sensitive city (Source: Brown *et al.*, 2009)

2.2 Five ‘big ideas’

A site inspection and a review of international practice in sustainable water management were instrumental to the development of five ‘big ideas’ that have underpinned the evolution of the water sensitive community master plan. These were presented to a variety of project and design stakeholders at a forum at West Belconnen in October 2013 and at an open Planning and Design Forum in November 2013.

2.2.1 ‘West Belconnen: a water neutral community’

There are two aspects to this first ‘big idea’. Firstly, it is the recognition that historically urban developments in Australia and across the globe have led to the deterioration of waterways, receiving waters, aquatic habitats and environmental asset values. Today, with the emergence of WSUD practice, it is possible to conceive urban forms and planning provisions that would improve on the detrimental impacts of past urban developments. Secondly, it is the acceptance that water is a precious finite resource and that all efforts should be made to establish a highly efficient community with reduced pressure on potable water systems and the environment.

Delivering on this idea would involve:

- Reducing the potable water demand by realising opportunities for non-potable water systems based on a ‘fit-for-purpose’ approach
- Reducing the wastewater and stormwater discharges to the local ephemeral waterways, Ginninderra Creek, and the Murrumbidgee River
- Understanding and mimicking the natural (or predevelopment) hydrology of the site to limit the alterations to the natural water cycle

2.2.2 ‘The city is your catchment’

Associated with the increase in imperviousness in urban catchment is the net increase in surface runoff. This has historically been considered the source of potential nuisance and led to the integration of flooding planning reserves and provision of drainage corridors in all modern Australian suburbs. More recently, this perception has shifted to recognise the water resource that is actually created from doing this and the multiple benefits and values of this water.

Underpinning the ‘city is your catchment’ idea is the principle of ‘fit-for-purpose’ in matching water resources and uses. Australian cities and towns have shown that they can be affected by water shortages and future water demands threaten to exceed supply in many regions. Opportunities can be explored to make use of these resources, alleviate the pressure on the potable system, and have other potential benefits, for example:

- Replacing the use of potable water for toilet flushing
- Creating more efficient infrastructure systems, for example in some locations large volumes of stormwater is discharged, while expensive infrastructure is built to transfer potable water from remote catchments over long distances
- Reversing the trend that sees treated wastewater that is high in nutrients being discharged to nutrient-sensitive rivers, while clean river water is extracted for irrigation, and nutrients need to be added to promote plant growth.

Many water demands do not require water of potable standard and opportunities exist to use alternative sources such as wastewater, stormwater or rainwater (collected roof runoff). In the right circumstances, the use of alternative water sources for non-potable demands has the benefits of alleviating environmental impacts that result from wastewater and stormwater pollution, whilst increasing water security. Different water uses require water of different quality to manage environmental and health risks to receptors. The management or treatment requirements depend on the level and frequency of exposure to the alternate water source.

At West Belconnen, a number of non-potable water uses were explored in terms of the water demands they generate, the water quality requirements to manage risks to the users, and matching these with alternate local water sources (while also considering quality management requirements). These included:

- Domestic hot water, laundry and toilet flushing
- Irrigation - four categories of irrigation areas are used, because each carries a different health risk profile due to the likelihood of human exposure to water. Water of a lower quality standard is acceptable for use due to the low likelihood of ingestion; however water should be treated for pathogens.
    - Private space irrigation

- Public space irrigation - active use areas
- Public space irrigation - passive uses
- Agriculture or forestry irrigation.

Treating the city as your catchment requires a number of initiatives:

- A commitment to ongoing stormwater quality improvement measures, *i.e.* an added incentive to maintain the WSUD infrastructure and quality of urban runoff to maintain the reliability of a beneficial resource
- Harvesting and using the stormwater as an alternative water source (*e.g.* through a 'third pipe' to garden, toilets, laundry), and deploying sensible onsite rainwater capture and use on blocks
- Maintaining community awareness and social values associated with not discharging pollution to urban stormwater networks and the environment.

This idea has particular resonance at the West Belconnen site which is basically a plateau bound by major natural waterways. As discussed later in this report, the site topography combined with the water flow and quality management requirements set out particularly in the ACT WSUD Code result in large volumes of water having to be captured, stored in various water bodies scattered over the site, and slowly released or otherwise used. This creates a particular opportunity to hold and beneficially reuse the stormwater, as the storage infrastructure requirements are being driven by environmental management needs.

2.2.3 'Make the landscape work'

The essential values of urban landscape to providing social and environmental amenities have been central to the integration of Public Open Space (POS), pedestrian and cycling networks, parks and reserves, particularly in Canberra. The urban landscape is commonly described as 'the backdrop', the setting in which human and urban activity takes place. It is most commonly associated with passive functions and values.

This 'big idea' emphasizes the more active role that could be played by our urban landscapes if they were to be considered functional landscapes or as 'green infrastructure'. By modifying slightly the configuration, layout and infrastructure associated with our urban landscape, it is possible to maximise its ability to deliver a much higher number of services including:

- Slowing down and infiltrating excess urban stormwater runoff
- Supporting stormwater treatment, by capturing urban pollutants in WSUD assets
- Maintaining soil moisture and passively irrigate POS
- Support the health of vegetated landscapes and improve their resilience to extreme weather conditions
- Recharge groundwater systems and mitigate the impact of imperviousness of groundwater systems
- Contribute to passively cool the urban areas by facilitating natural evapotranspiration by plants and trees
- Create a micro-climate that is cooler, less susceptible to the effect of urban heat island and heat waves
- Support more active and liveable urban communities

2.2.4 'Produce the food you consume'

The pressure on global food resources is increasing, directly in line with the growing global population. Simultaneously, there is also a growing consciousness and interest in the general public for locally produced food. In Canberra this has translated to the success and multiplication of farmers markets over recent years.

One of the most beneficial and profitable ways of using the urban stormwater resource is to harvest the water and use it to irrigate productive crops. Additionally, it is also possible to use treated/recycled wastewater to irrigate many market crops, subject to appropriate water quality control, monitoring and management.

Delivering on this idea would involve:

- Harvesting stormwater in the first instance to contribute to reducing the urban stormwater excess
- Considering a wastewater recycling scheme for irrigation
- Reduce the total environmental footprint of the West Belconnen community in the long term

In addition to irrigation food and market crops, it is readily conceivable that the same water sources could be used to irrigate urban planting, orchards, fruit and nut trees.

2.2.5 ‘Make the city work for waterways’

The most ambitious ‘big idea’ relies on completely shifting the urban development paradigm around environmental impacts and externalities. This idea suggests that rather than considering the proposed urban development project as a risk to the environmental values of the site and the area, it could be seen as an opportunity to not only secure the protection of the environmental assets in the long term by careful planning and responsive design but also repair the various currently degraded ecosystems by applying restorative urbanism principles.

The current site conditions, with near complete clearing of trees and understorey, and a long history of grazing and pastoral practices, is in many places quite degraded. While there are undoubtedly significant remaining environmental values, particularly in the proposed Murrumbidgee River corridor, many ephemeral creek lines have experience intense erosion and degradation over the last 100 years.

By including many of these as part of the ‘green infrastructure’ network for the project there is an opportunity to restore these environmental assets.

Key initiatives that would deliver on this idea include:

- An extensive network of drainage corridors, WSUD measures (*e.g.* ponds and wetlands), and use of existing farm dams that connect and control stormwater flows
- A controlled hydrological regime that mimics the current undeveloped hydrological regime of the site
- Restoring and rehabilitating the many drainage lines that are currently degraded
- Improved sediment and erosion control during the construction phase of the project
- Careful integration of environmental values in the design and selection of stormwater discharge points across the river corridor into the Murrumbidgee River.

This ‘big idea’ requires the prioritising of water management requirements at a higher level than what is standard in many urban development projects – it involves a commitment to maintain or enhance the more natural features of the water ways, rather than deploying, for example, concretes channel lines because they are straightforward to maintain. While the techniques and technology involved are now established, it is the combination and integration of a range of initiatives that constitutes the innovative nature of this idea.

2.3 Relevant international practices

On their own, none of the ‘big ideas’ or initiatives that have been considered above for West Belconnen are new. There are many examples of initiatives and schemes that have been designed and constructed across Australia and internationally that have addressed a particular dimension of an integrated water management. However, the innovation resides in the integrated application of these ideas at West Belconnen and how they respond to the unique natures and constraints at the site.

When first gathered to review the West Belconnen site specific opportunities and constraints, the team of WSUD experts and practitioners also held a strategic internal practice review workshop with the intent to derive relevant examples and case studies from Australia and internationally.

The case studies were selected to address issues particularly relevant to the West Belconnen project:

- Non potable water supply, including rainwater, stormwater and wastewater
- Hydrological regime management

There are various examples and case studies from Australia and elsewhere that illustrate the application of the concepts that are being put forward for West Belconnen. The selected case studies are summarised in Table 2 and presented in more details in the following page.

Table 2 **Summary of selected case-studies implementing alternate water sources for large-scale domestic uses**

Name of project / location	'Third pipe' non-potable water supply for domestic uses via…		
	Rain water	Storm water	Waste water
Rouse Hill, NSW			X
Aurora, Vic			X
West Werribee, Vic			X
City of Casey, Vic		X	X
Currumbin Eco-village, Qld	X		X
Troupe's Creek, Vic		X	
Googong New Town, NSW			X
Rural Australia	X		
London Olympic Park, UK		X	X
NEWater, Singapore			X
San Francisco, USA			

Table 3 **Summary of selected case-studies for innovative hydrological regime management**

	Name of Project	
	Little Stringy Bark Creek	Officer Bio-sponges
Rainwater tanks for non-potable demand	X	
Charged down pipes to rainwater tank (whole roof catchment)	X	
'End of pipe' treatment measures		X
Distributed WSUD measures	X	
Surface water flow volume reduction measures	X	X
Surface water flow frequency reduction measures	X	X

2.3.1 Rouse Hill (Sydney Water)

The Rouse Hill Recycled Water Scheme is the largest residential water recycling scheme in Australia. The scheme began in 2001. It supplies recycled water to over 60,000 people and serves an area of 13,300 hectares. In addition to establishing a highly reliable non potable water supply, contributing to reducing potable water demand, the scheme also helps to care for the environment and reduce impacts on waterways, by reducing the amount of treated wastewater discharged to the Hawkesbury-Nepean River. On average, customers in the Rouse Hill recycled water area use up to 40% less drinking water than other customers in greater Sydney.

2.3.2 Aurora (Yarra Valley Water)

The Aurora estate in Melbourne's north urban fringe (Epping North) pursued a strategy to address all aspects of the water cycle holistically. The scheme was designed to serve 8,500 homes and currently serves 2,500 with recycled water for toilet flushing, laundry and garden watering as well as public open space irrigation. It took around 8 years to progress from the earliest feasibility discussions to commissioning the recycled water treatment plant in 2009. Stormwater is treated through distributed treatment on lots and in streets including rain gardens implemented within household lots. Natural waterways throughout the development were protected and retained.

2.3.3 West Werribee Dual Supply Scheme (City West Water)

City West Water is implementing a wastewater recycling scheme in the West Werribee area to supply new residential developments and open spaces. A shandy of treated wastewater and salt-reduced treated wastewater from the Werribee (Wastewater) Treatment Plant is delivered through a ‘third-pipe’ system to all new developments. It was expected that more than 3,000 lots would be connected at commencement of supply in 2013. At full development in 2035 the system will supply over 19,000 residential lots and 143 hectares of open space with recycled wastewater for toilet flushing and irrigation use. The project was carefully planned and staged to optimise the system for variations in demand, supply and development. Trials are also being undertaken to integrate an aquifer storage and recovery system (ASR) that will enable winter production of treated wastewater for use during summer. Further investigations are also being undertaken to integrate treated stormwater sources with the reticulation system.

2.3.4 Casey (City of Casey and Melbourne Water)

An integrated water management strategy was developed to provide a vision and implementation plan to guide the City of Casey's management of water. A business case was developed and demonstrated that pro-active maintenance of its WSUD assets would have similar (slightly higher) costs than reactive maintenance and replacement of failed assets yet delivering significantly greater benefits to the local and broader community. This underlines the importance of establishing effective maintenance programs when assets are designed and constructed. It was also shown that with recent increases in the price of water there were numerous cost effective opportunities to reduce both water use and costs through facilities demand management, introduction of warm season grasses and uptake of opportunities to use recycled water to substitute potable water use.

2.3.5 Currumbin (The Ecovillage at Currumbin)

The Eco-village in Currumbin is a small estate home to over 200 people and several small businesses. The community contains 147 lots over 110 ha of land, in the most southern hinterland of the Gold Coast in Queensland. The project achieves both water and wastewater self-sufficiency and includes a range of WSUD measures, including stormwater harvesting initiatives. Interestingly, the infrastructure investigations and all decisions relating to infrastructure on this project were based on long term life cycle assessment principles rather than simply upfront capital cost.

(Credit: courtesy of Bligh Tanner, 2012)
Figure 5 Rainwater harvesting infrastructure at Currumbin Eco-village, Queensland

2.3.6 Troups Creek Estate (South East Water)

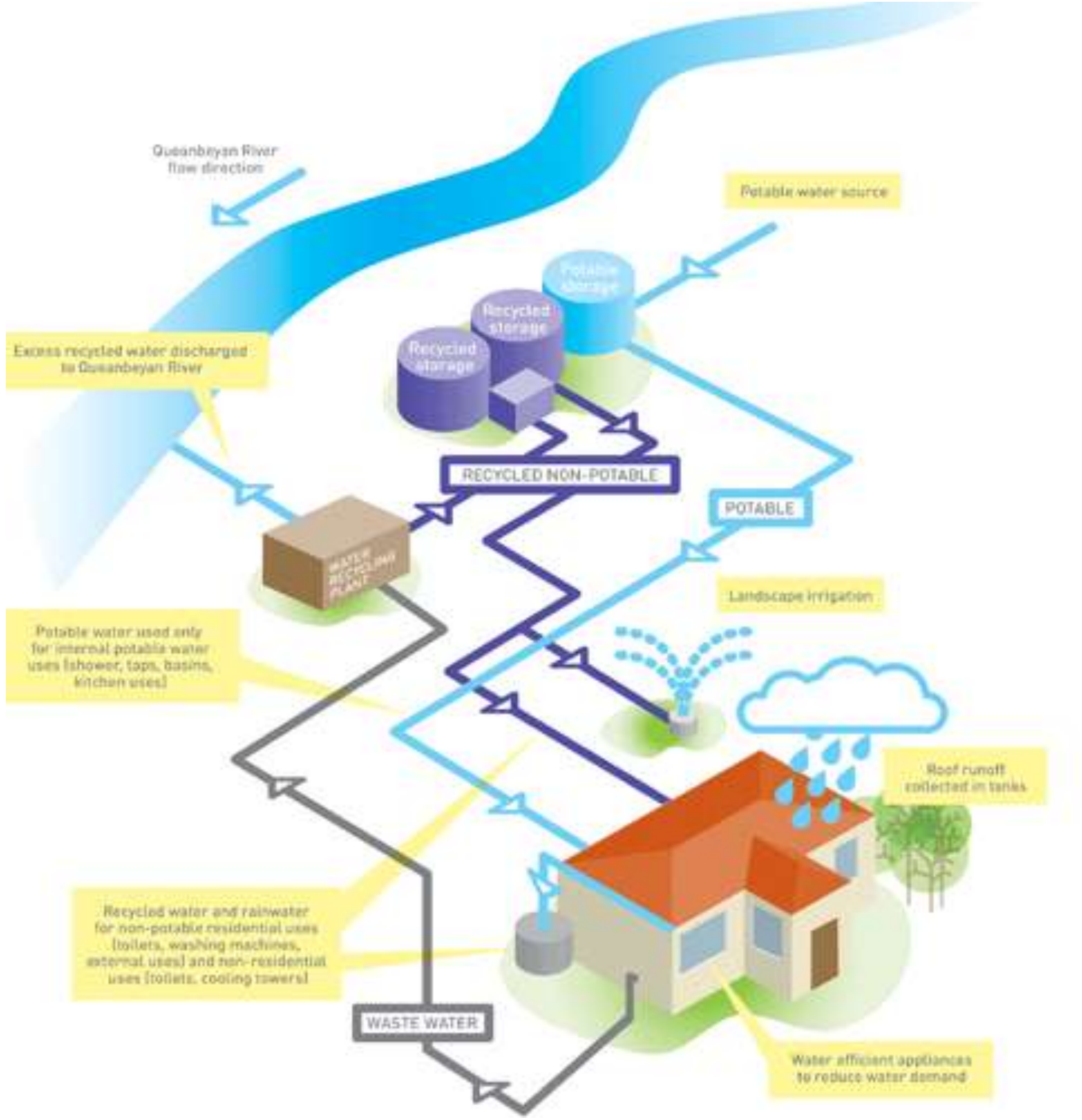
The Drysdale Avenue residential development aimed to set a new benchmark for water sustainability. It incorporates a stormwater harvesting scheme to treat urban stormwater excess from Troups Creek for reticulation and use within households for toilet flushing and irrigation. The strategy for the development resolved a number of planning, aesthetic and maintenance issues for adjacent public land. It attains best practice stormwater quality treatment and aspires to a 50-75% reduction in potable water use through various initiatives including the stormwater reuse scheme.

2.3.7 Googong New Town (ACTEW Water, Queanbeyan City Council, CIC Australia)

Located in the immediate south of Queanbeyan, the Googong New Town development will be home to 16,000 residents when completed. The integrated water cycle management proposed at Googong was largely influenced by the ACT WSUD Code principles and objectives. The close collaboration between the utility (ACTEW Water), developer (CIC Australia) and Queanbeyan City Council means that it also includes a dual reticulation network from a water recycling plant treating wastewater generated on the site. It is expected that the development will achieve significant water quality improvement and a reduction in potable water demand of approximately 60%. It will also significantly reduce the discharge of treated effluent to the Queanbeyan River.

(Credit: Googong Township Pty Ltd[4])

Figure 6 Googong Integrated Water Cycle Schematic



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[4] Accessed at http://googong.net/, September 2014

2.3.8 Rural Australia (off grid, over 100 years)

Across the vast majority of rural Australia, there is no centralised potable water supply. For a large number of rural communities, potable water is sourced from rainfall over the roofed areas and stored in large rainwater tanks. New rural townships in and around the ACT, including at Murrumbateman (NSW), are still deploying rainwater tanks as the primary and sole household water source.

(Credit: *The Biggest Family Album of Australia*, Museum Victoria)
Figure 7 Rural homestead with corrugated iron roofing and rainwater tank (Horsham district, Victoria, *ca.*1920-1930)

(Credit: Rhino Water Tank)
Figure 8 Modern rural property with charged downpipes and a 60,000L rainwater tank

2.3.9 London Olympic Park, Norwest Cambridge Ecotown (UK)

In the United Kingdom, surface water flooding issues have led to the requirement that new development meets greenfield runoff rates by providing attenuation or infiltration measures on site which reduce the volume and flow rate of stormwater from a site. Common practices include the installation of retention basins, underground storage tanks, and source control measures like rainwater harvesting, permeable paving, green roofs and infiltration areas. Drier areas in the south-east of England are also focussed on reducing pressure on potable water supplies. Some of the planned new towns, known as ‘ecotowns’, are required to be water neutral, where water efficiency and recycling measures are used to reduce external supply while existing homes in the area are retrofitted with water saving measures to offset the remainder of demand. The London 2012 Olympic Park delivered stormwater treatment systems along with a sewer mining plant which recycles water for toilet flushing and irrigation on-site. The reuse of stormwater on a large scale is being piloted on a 3,000 home development site in Northwest Cambridge, where stormwater is naturally treated then redistributed for toilet flushing and clothes washing.

(Credit: Inhabitat[5])
Figure 9 London Olympic Park green infrastructure

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[5] Accessed at http://inhabitat.com/tag/london-olympics/, September 2014

2.3.10 NEWater (Singapore Public Utility Board)

NEWater is an integrated water cycle management scheme that extends over most of Singapore. Starting back in the 1970s, the efforts of the Singapore Public Utility Board culminated in 2010 with the opening of the largest of the NEWater water recycling plants in Changi. With multiple water recycling plants currently meeting 30% of Singapore's water requirements, the master plan includes an expansion of the scheme by 2060 to triple the current production capacity and meeting up to 55% of the future demand of the state. This scheme is central to the long term water security and strategy for Singapore where natural resources are already nearly fully exploited and the prospect of detrimental impact on the growing economy is real.

A successful scheme, with a demand increasing 15 times over the past decade, NEWater primarily supplies industrial demands such as to wafer fabrication, electronics and power generation industries for process use, it is also piped to commercial and institutional buildings for air conditioning cooling purposes. A small percentage of the recycled water is also blended with raw water in Singapore water supply reservoirs and goes into the potable water network once treated in the water supply treatment works. This scheme has put Singapore on the world map for innovative water management, including winning for PUB the Stockholm Industry Water Award in 2007.

(Credit: NEWater[6])

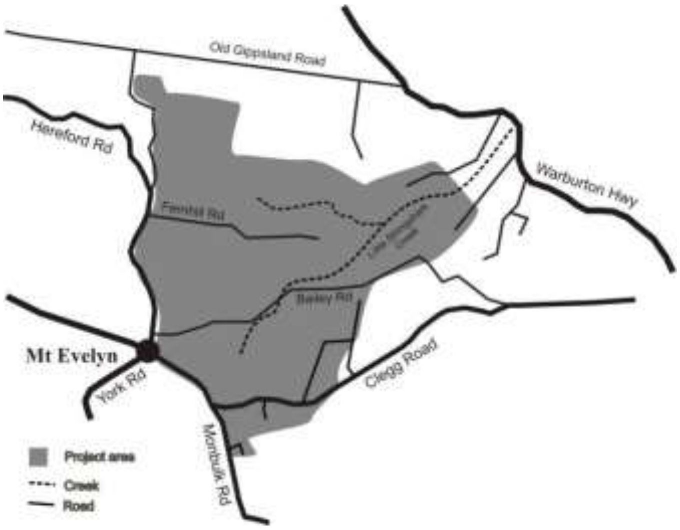
Figure 10 NEWater Visitor Centre and water recycling plant

2.3.11 Little Stringy Bark (University of Melbourne, Melbourne Water)

The Little Stringy Bark project[7] is a large scale research-based project initiated in 2008 which aims at demonstrating the environmental and ecological benefit of urban stormwater excess reduction. Located in the Dandenong Ranges in Victoria, the project which is ongoing involves the retrofitting of a range of WSUD measures in the private and public realms. These measures primarily seek to capture and reduce the urban stormwater excess and to improve water quality.

To date, the project has delivered:

- 230 Residential allotments
- 36 Nature strip rain-gardens
- 11 Neighbourhood rain-gardens
- 2.8 ML of water storage (tanks)
- 64 ML of stormwater treated per year
- 15 ha of catchment treated.



Courtesy: Prof. Tim Fletcher, University of Melbourne

Figure 11 **Little Stringy Bark Creek project area**

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[6] Accessed at www.wisatasingapura.sg, September 2013

[7] Details are at http://www.urbanstreams.unimelb.edu.au/, accessed September 2014

2.3.12 Officer Bio-Sponges

Located near Lilydale in the East of Melbourne, the Officer Bio-Sponge project by the Cooperative Research Centre for Water Sensitive Cities uses end-of-pipe measures designed as bio-sponges that trap and slowly release or evaporate urban stormwater excess in order to protect the downstream Gum Scrub Creek. Attenuating these flows, the bio-sponges allow the water to slowly filter through the porous densely vegetated riparian sponge, thus being released into the creek in a way that:

- Emulates the natural flow processes (the vast majority of flows arriving in the creek through sub-surface means)
- Emulates the natural filtration processes (which are delivered through these densely vegetated riparian sponges).

(Credit: CRC Water Sensitive Cities[8])
Figure 12 Officer Bio-sponges

2.4 Technology

A range of potential technologies will be proposed for implementation at West Belconnen, as described below.

2.4.1 Constructed wetlands

Wetland systems use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. The wetland processes are engaged by slowly passing runoff through heavily vegetated areas where plants filter sediments and pollutants from the water. Biofilms that grow on the plants also absorb nutrients and other associated contaminants. Constructed wetlands for stormwater treatment are artificially made shallow, marshy and extensively vegetated water bodies which fill and drain with rain events.

They can work successfully in flat areas as very little grade difference is required to convey water through the wetland. They are ideal for locations where treatment is required at the bottom of the catchment as they can be easily scaled up to accommodate flows from large catchments. The key functions of wetlands are to:

- Reduce peak flows
- Manage hydrological regime
- Trap pollutants and improve water quality
- Support stormwater harvesting
- Create habitat and amenity.

Wetlands are also complementary habitat for low-lying or flood prone areas and swampy habitats. Wetlands provide habitat for aquatic flora and fauna, and contribute substantially to the scenic amenity of public open spaces. The wetland will provide significant native habitat and public amenity and provides greater diversity than ponds.

The wetlands generally have the following elements (refer to Figure 13):

- An inlet zone which reduces the velocity of inflowing water and traps coarse materials
- A macrophyte zone which the main zone of the wetlands and is a heavily vegetated area of different water depths that removes fine particulates and take up soluble pollutants
- An outlet zone (or deep pool) which holds water prior to release to enable the settling of fine particles not removed in the macrophyte zone.

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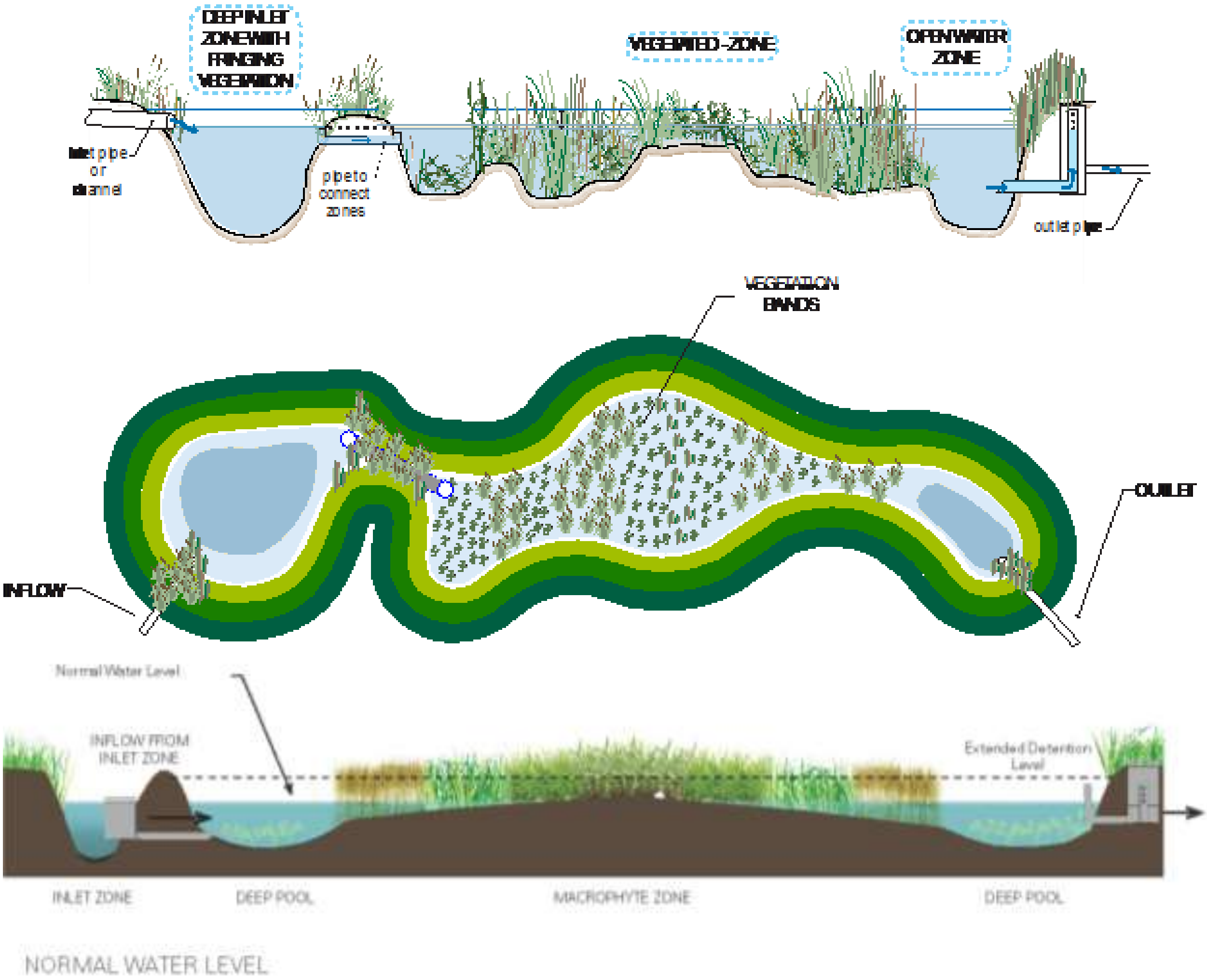
[8] Details at http://watersensitivecities.org.au/, Accessed September 2014

A wetland may consist of one or multiple combinations of the above elements.

Figure 13 Typical arrangement of a constructed wetland



2.4.2 Ponds

Stormwater quality control ponds and lakes (referred herein as ponds) are larger open water bodies where stormwater quality improvement is gained from the exposure to the littoral vegetation that would represent 10-30% of the surface area of the pond and a slow process of deposition of fine material to the bottom of the ponds where they become trapped.

Ponds are artificial bodies of deep (>1.5m) open water. These water bodies can be located downstream of a wetland and act as a storage and detention mechanism for stormwater flows. Ponds/lakes can be retrofitted for future stormwater harvesting.

Photo credit: G Pecham, 2011[9]
Figure 14 Gungahlin Pond

The key functions of ponds are to:

- Reduce peak flows
- Manage hydrological regime
- Trap pollutants and improve water quality
- Support stormwater harvesting
- Create habitat and amenity.

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[9] Accessed at http://www.bonzle.com/pictures-over-time/pictures-taken-in-2011/page-1/australian-lakes-and-dams/size-3/picture-w8qnd788/gungahlin-pond/gungahlin-pond, September 2014

2.4.3 Bioretention systems

Bioretention systems are commonly swales or basins. Bioretention systems are vegetated filter systems designed to allow water to pool temporarily before percolating through the filter media. The filter media controls the flow rate of water through the system, as well as providing a growing media for the plants. The filtered water is directed via perforated pipes to the existing stormwater system, natural waterway or a detention basin for reuse.

Bioretention systems can be implemented in many sizes and shapes to fit different locations, for example, planter boxes, parks or streetscapes. It is important to have sufficient depth (normally at least 0.8 metres) between the inlet and outlet. They may not be suitable at sites with shallow bedrock or other sites with depth constraints. Bioretention systems require sloping sites in order to discharge treated water below surface level, they are ideally suited for use in the upper urban catchments. They do no perform well for end of pipe treatment of large catchments. Despite this, bioretention systems are a very flexible and effective treatment measure for dissolved nutrients.

In steep streets (beyond 6% longitudinal grade) small bio retention planting beds or street tree pits can be used, however the fall across these systems limits their use. In such cases, the verge finish options available may include site sourced angular gravel mulches, turf or groundcover planting.

If planting either turf or groundcovers there will be a requirement to water throughout dry seasons using water made available through the water recycling plant and allow irrigation of these systems to be supplemented with potable water when the availability of recycled water is limited.

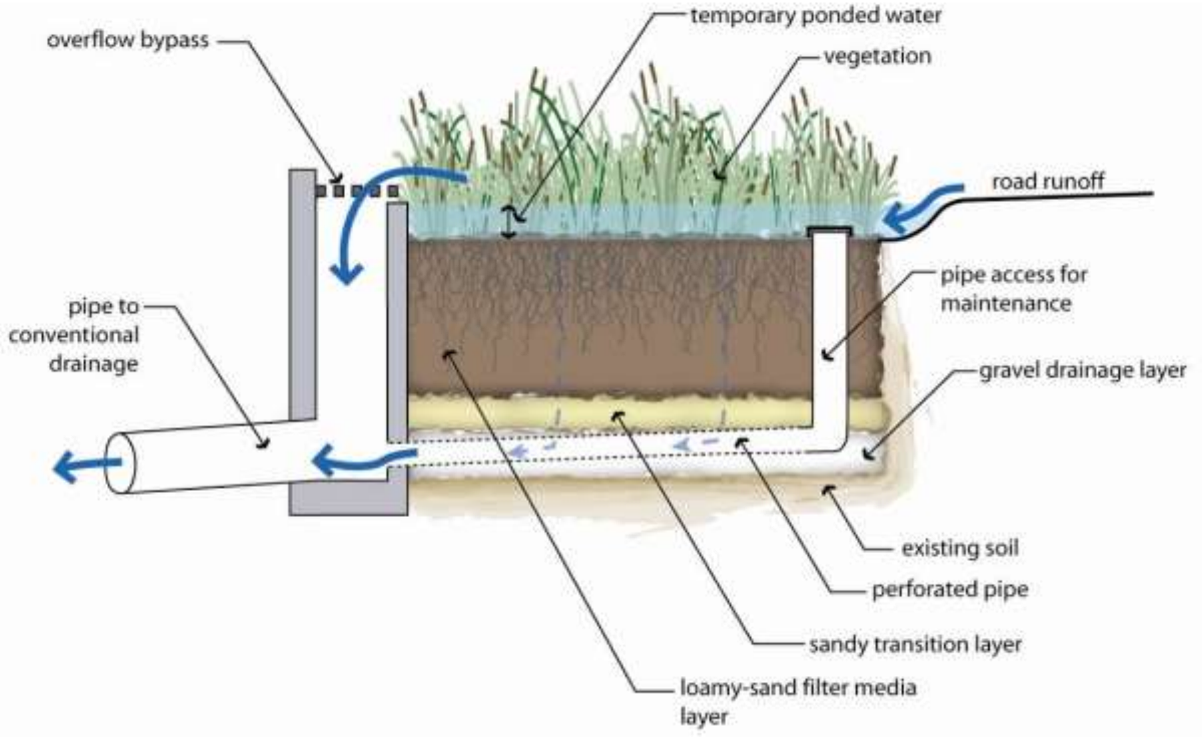

Figure 15 **Typical configuration of a bioretention system**

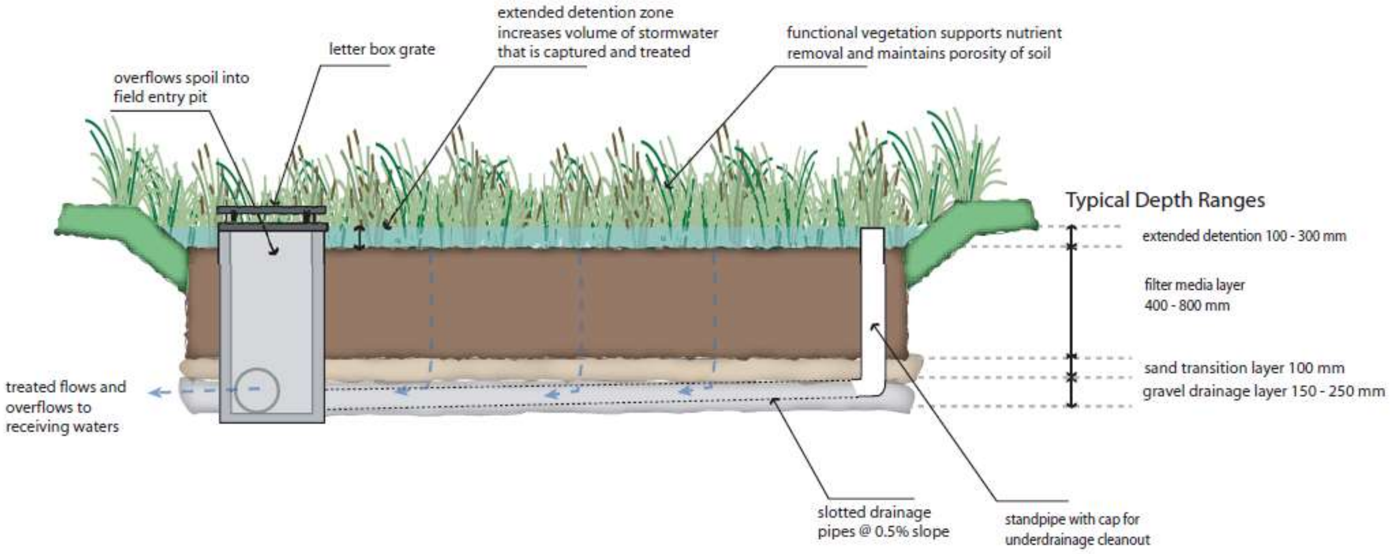

Figure 16 Rain gardens

Bioretention systems are designated with a wide range of terms including: rain gardens, tree pits, bioswales, etc. but all these systems rely on the same fundamental processes and treatment structure. They consist of an area of planted filtration media, typically organised in a series of cells that allow for larger flows to be treated. Water only pools in bioretention basins for a limited period of 24-72 hours and the basins are dry at the surface at other times.

As part of the present strategy, it is noted that there are proposals for small scale bioretention systems (rain gardens, Figure 16) to be included in the proposed ‘biostreets’ (McGregor Coxall, 2014) as at Appendix d. While these will be beneficial and would contribute to improving the water quality from the West Belconnen urban areas, they are too small and too uncertain to be relied on for this strategy. In this report all references to bioretention systems relate to larger catchment-scale measures.

The key functions of bioretention systems are to:

- Reduce small frequent storm flow and frequency
- Manage hydrological regime
- Trap pollutants and improve water quality
- Create amenity.

2.4.4 Stormwater harvesting

This refers to the capture, treatment and use of runoff from impervious surfaces such as roads and paved/hardstand areas. Stormwater runoff is separated into two categories:

- Rainwater (roof runoff)
- Stormwater (urban runoff).

Treated stormwater reuse protects the receiving environment through the reduction in pollutant loads and a reduction in the hydrologic disturbance to streams and aquatic ecosystems (*i.e.* they lessen the 'days of runoff' or periods where excess surface water is flowing in addition to waterway 'base' flows).

The key functions of stormwater harvesting are to:

- Reduce peak flows
- Manage hydrological regime
- Support 'fit-for-purpose' water supply principles (when it is demonstrated as safe and economically sound to do so)
- Reduce reliance on potable water and improve reliability and resilience of the community water supply.

Credit: City of Casey[10]
Figure 17 Grices Road Reserve stormwater harvesting interpretive signage

2.4.5 Rainwater to the home

Generally defined as the runoff from roofs, rainwater will typically have a more consistent water quality profile with a better overall quality than stormwater resultant from road and pavement runoff.

The ACT WSUD Code advocates for the use of rainwater tanks on all new dwellings. Either above or below ground, rainwater tanks collect water from roofs via gutters and downpipes. The main purpose of the tank is to provide storage, although some treatment, mainly particles settlement, occurs in the tank as well. Rainwater runoff from roofs can be captured and is used in various parts of Australia already for toilet flushing, irrigation, washing machines and hot water systems. The reliability of supply of harvested rainwater will depend on the temporal demand patterns (*i.e.* does the demand for the water vary seasonally or is it largely uniform across the year?), catchment area and the size of buffer storages used. Rainwater tanks are of most benefit if they are plumbed into suitable devices that have a regular demand, for example, toilets, laundry or hot water.

In the context of West Belconnen and the ACT WSUD Code, the key functions of rainwater collection systems are to:

- Manage the hydrological regime, by providing capture and storage of water that may otherwise become surface runoff
- Support fit-for-purpose water supply
- Improve reliability and resilience of water resources while managing the stress placed on the main potable water system.

Rainwater is a generally accepted source of water for uses such as toilet flushing and irrigation at the home. In some, mainly rural, areas it is also used as a hot water source and the primary drinking water source. For this study the option of using rainwater as a hot water source for homes at West Belconnen has been considered, mainly because it can create additional rainfall capture and storage volumes through the development, and assist with minimising overland flow volumes following storms which is an important consideration at this site, given the need to attenuate flows into the sensitive gullies of the adjacent river corridor. Admittedly such an approach is rare in an urban setting when potable water is available, and so it will be important to demonstrate that the rainwater is suitable for this purpose and comparable to potable water. In recent times there have been studies into the water quality and health risks associated with rain-to-hot water systems, on the basis that such systems heighten exposure to uncontrolled and untreated water qualities as compared to the other uses for rainwater like garden

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[10] Accessed at: http://www.clearwater.asn.au/resource-library/case-studies/casey-stormwater-harvesting-and-re-use-projects.php, September 2014

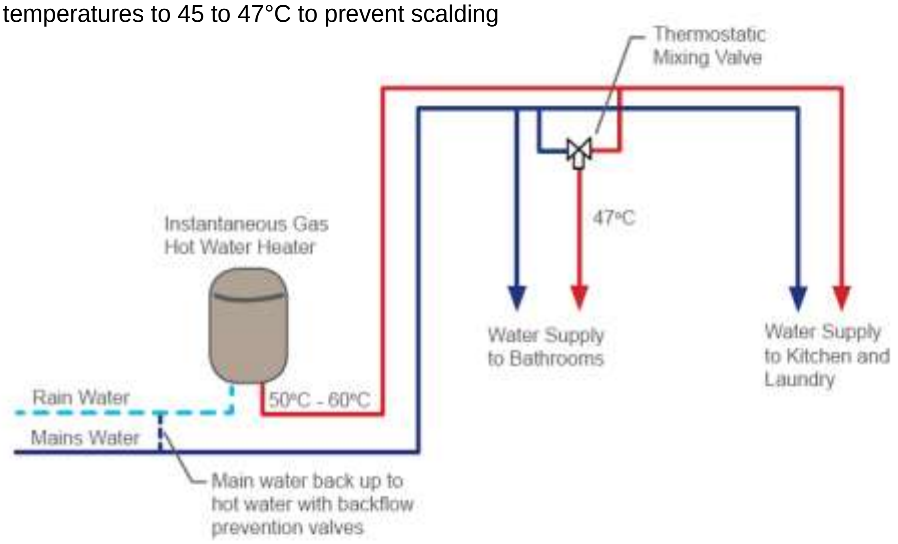
watering and toilet flushing. Research has shown that storing rainwater collected from roofs in a system at temperature ≥ 60℃ for an extended length of time can provide extensive inactivation of microbial pathogens, a primary health hazard to water users. This means that pathogens like *Salmonella*, *Campylobacter* and pathogenic *E. coli* that can be found in roof water can be well managed and inactivated, and health risks to humans can be adequately managed, which is a primary aim for any water supply system. Current convention has it that new continuous flow hot water systems that use potable water typically have water temperatures set between 37℃ and 50℃ (for scalding prevention) and do not store the water at those temperatures for significant lengths of times. Deere *et al.* (2012) in a study for Water Quality Research Australia (WQRA) hypothesises that such continuous flow systems do not offer adequate health risk management in accordance with the *Australian Water Recycling Guidelines* ([AGWR] NHMRC, 2006) unless additional measures, such as ultra-violet (UV) disinfection, is installed. Such a measure would also typically meet the *Australian Drinking Water Guidelines* ([ADWG] NHMRC, 2011) criterion of having *E. Coli* levels at below detection limits in 100 mL water samples.

The WQRA report suggests that installing a control in the hot water system that does not allow hot water to be fed unless heated to above 60℃ would be one way to manage the risk. Additionally, the system should also ensure that hot water is tempered by the mains water supply and not the cold rainwater.

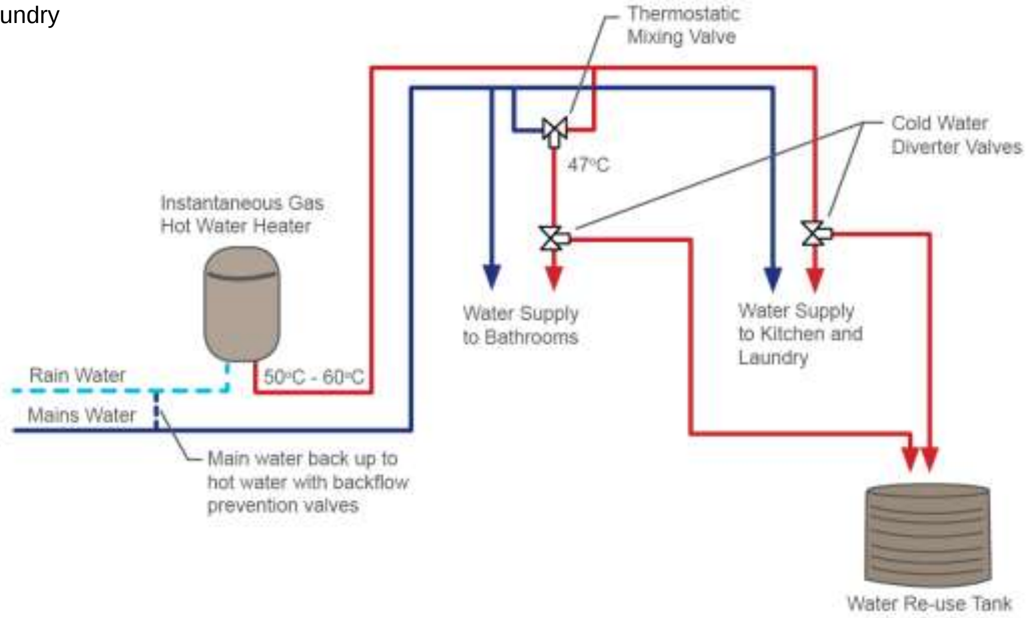
Possible arrangements for such a system are shown at Figure 18 with notes.

Figure 18 **Possible rainwater to hot-water system arrangements**

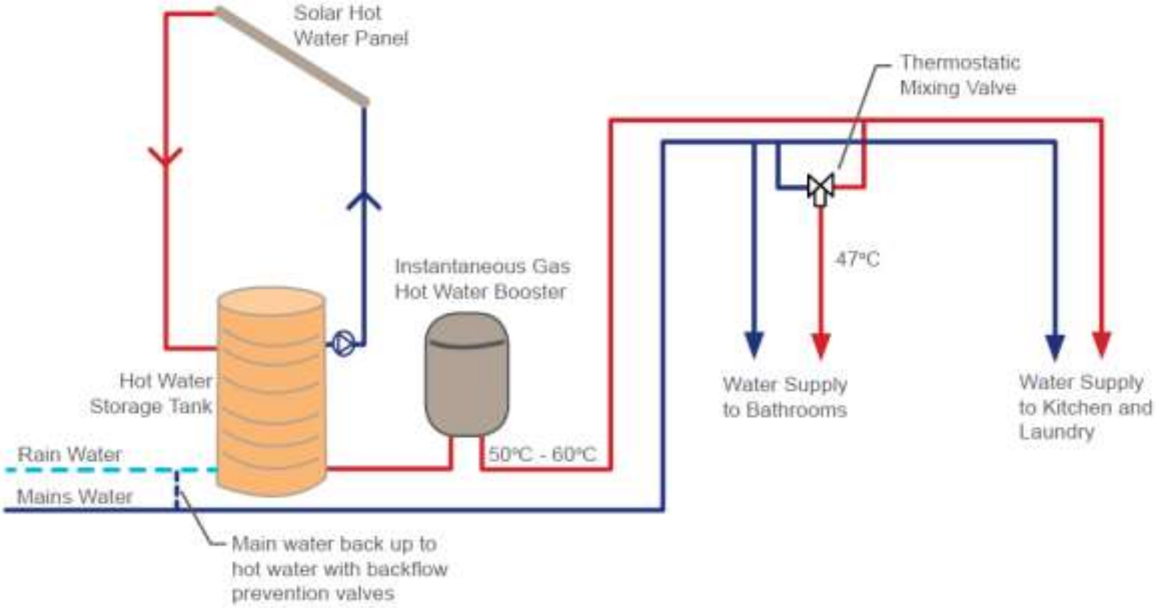
Option 1A is an instantaneous gas hot water system that can deliver between 50 to 60°C hot water to the household. Thermostatic mixing valves are provided adjacent to bathrooms to mix hot water with potable cold water and drop the temperatures to 45 to 47°C to prevent scalding



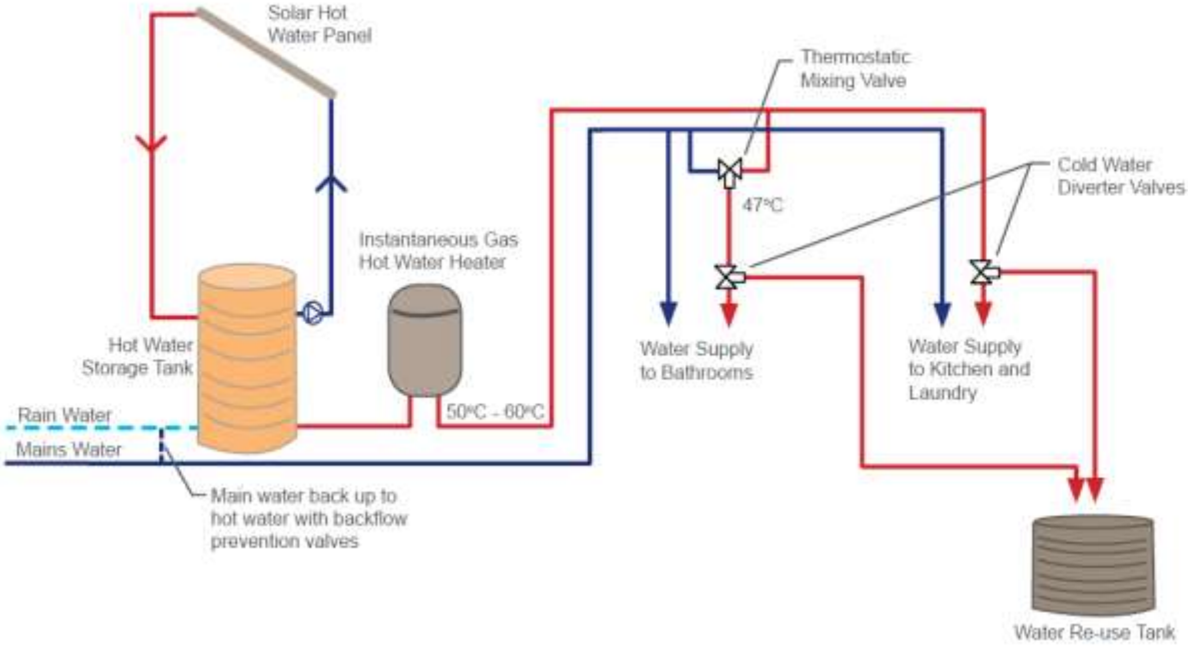
Option 1B is the same as above but with a cold water diverter system that diverts cold water in the hot water pipework to a storage tank until the hot water gets up to temperature. The tank water could then be reused for irrigation or in the laundry



Option 2A is a solar heating solution with roof mounted collector, a thermally stratified storage tank and a gas hot water booster to keep the hot water above the required supply temperature on overcast days. Similar to Option 1A thermostatic mixing valves are provided to reduce the scalding risk



Option 2B is the same as Option 2A but with a cold water diverter as described in Option 1B.



2.4.6 Recycled water reuse

Recycled water is the generic term for wastewater reclamation and reuse. With appropriate management recycled water is typically suitable for a range of applications including industrial uses and toilet flushing. The recycled water is split into two types:

- Grey water is water collected from uses where minimal contamination may have occurred such as the water from basins, showers, baths and certain sinks
- Blackwater is water that has been contaminated with bodily fluids or with organic matter, i.e. toilet and kitchen sinks.

The proximity of the site near to the Lower Molonglo Water Quality Control Centre, one of Canberra's major wastewater treatment plants and one that provides recycled water for agricultural and irrigation uses around the region already, provided an opportunity to explore the potential for wastewater recycling at the West Belconnen site.

The key functions of recycled water reuse are to:

- Reduce reliance on the primary potable water system, when the water source matches the intended purpose, can be treated and managed appropriately, and it is economically advantageous
- Improve reliability and resilience of water resources on the project
- Reduce treated effluent discharge to the environment.

Credit: Aquacell[11]
Figure 19 Non potable water reuse (recycled water) infrastructure at household

2.4.7 Flood attenuation

Attenuation of flood water can be provided by providing temporary flood storage above constructed wetlands and ponds (primary WSUD measures) in urban areas. Attenuation is provided by a large bund (~ 1m high) around the wetland / pond, and an outlet weir or pipe to control the discharge.

The key objectives of flood attenuation are to:

- Reduce peak flows
- Manage hydrological regime
- Protect natural and built assets downstream of the development.

Credit: National Capital Development Commission[12]
Figure 20 Lake Ginninderra in the late 1970's. (Credit:

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[11] Accessed at http://aquacell.com.au/resources/information-for-plumbing-contractors/, September 2014

[12] Accessed via Engineers Australia website: http://www.engineer.org.au/images/4-7.jpg, September 2014

2.5 Green Star Communities – Pilot Scheme

2.5.1 Overview

The Green Building Council of Australia (GBCA) was established in 2002 to develop sustainable practices within the property industry. The GBCA operates the Green Star scheme which is a sustainability rating system for the built environment. The sustainable practices that are promoted by Green Star include reducing the impact of developments, improving occupant health and productivity, realizing cost savings and promoting innovation.

More recently, the *Green Star – Communities PILOT* rating tool has been developed to evaluate projects at a precinct, neighbourhood and community scale. The West Belconnen project is a pilot partner with the GBCA to assess the scheme and provide feedback on its uses prior to the final scheme being launched, and as such the ‘water-related’ criteria from the tool have been consulted and considered for this planning study. The rating tool has been developed by the GBCA in close collaboration with the market, including all three tiers of government, public and private sector developers, professional services providers, academia, product manufacturers and suppliers and other industry stakeholder groups (GBCA, 2014).The most recent version of the tool incorporates 35 scoring credits to assess the sustainability performance of projects’ planning, design and construction outcomes across the following sustainability categories:

- Governance (GOV)
- Design (DES)
- Liveability (LIV)
- Economic Prosperity (ECO)
- Environment (ENV)
- Innovation (INN)

An independent assessment panel awards points to the *Green Star - Communities* projects based on how well they deliver against each category, and a Green Star rating is subsequently determined by comparing the overall score with the following rating scale:

Point Score	**Green Star Rating**	**Outcome**
45 – 59	4 Star	Best Practice
60 – 74	5 Star	Australian Excellence
75+	6 Star	World Leader

Projects cannot achieve ratings of 1, 2 or 3 Stars at certification, as these ratings represent minimum, average and good practice respectively. The rating system aims to recognise and reward projects that achieve best practice outcomes or better.

Each of the major categories has a number of associated scoring credits against which points are allocated. The *Green Star – Communities PILOT Submission Guideline* (GBCA, 2013) describes all the criteria and scoring objectives. Scores are calculated from a total of 100 possible points and then a star rating is achieved dependent on that score. This is exclusive of the innovation category which is scored separately and can provide an additional 10 points. Therefore a total of 110 points are on offer.

To achieve a Green Star Rating of four, five or six stars a project must attain a minimum category score and total score. Green Star awards market leaders so scores that achieve less than the four star criteria are not recognised. The distribution of points that are achieved versus minimum credits per category that must be met is illustrated in Table 4. The total number of points that can be achieved in each category is shown in Table 5. Each category is divided into its particular credits which are divided into particular criterion.

Table 4 ***Green Star Communities*** **scheme – star rating achievement requirements**

Rating	Total score	Minimum category score					Outcome
		GOV	DES	LIV	ECON	ENV	
Four Star	45-59	3	2	3	3	4	Australian Best Practice
Five Star	60-74	5	3	6	5	7	Australian Excellence
Six Star	75+	7	4	8	7	9	World Leadership

Table 5 ***Green Star Communities*** **scheme - points allocations**

Category	Points allocation
GOV	21
DES	11
LIV	23
ECON	19
ENV	26
Sub-Total	100
INN-1	10
TOTAL	**110**

2.5.2 Water related credits

The project team has identified the following credits as critical or relevant to the water management on site. There are two critical credits and six relevant credits applicable to IWCM and WSUD. These credits and their related points are described in Table 6.

Table 6 **Summary of Water Related Credit for Green Star Rating**

Credit code	Credit title	Points available	Credit status
ENV-7	Potable Water Consumption	2	**Critical**
ENV-8	Stormwater	3	**Critical**
GOV-6	Adaption and Resilience	4	Relevant
LIV-3	Healthy and Active Living	5	Relevant
LIV-4	Access to Fresh Food	2	Relevant
ECON-8	Peak Electricity Demand	1	Relevant
ENV-2	Ecological Enhancement	2	Relevant
ENV-3	Heat Island Effect	1	Relevant
INN-1	Innovation	10	Relevant
TOTAL POINTS		**30**	

The critical and relevant criteria are summarised below. A critique of the critical criteria requirements and an explanation on the how the other criteria are relevant is also detailed.

2.5.3 Critical credit ENV-7 potable water consumption

Aim of credit

“To encourage and recognise projects that minimise consumption of potable water.” (GBCA, 2013:223)

This credit assesses a project’s capacity to provide alternative water sources while also monitoring potable water sources for leaks.

Credit criteria and compliance requirements

There are two criteria and two points available for this credit: (i) alternative water sources and (ii) leak detection. Alternate water sources are considered to be water recycling plants or rainwater harvesting systems (this does not include lakes, rivers or groundwater). Additionally, a leak detection system monitors potable water sources for leaks in real-time, noting leak are a significant source of potable water wastage Australia-wide. The credit and compliance requirements for each criterion are summarised below in Table 7.

Table 7 Potable water consumption credit criteria and compliance requirements

Criterion intent	Compliance requirements
Alternative Water Sources – 1 point available	
All landscape watering does not require irrigation	Local alternative water pipelines that can be connected to such as water recycling plants or rainwater tanks Must demonstrate that landscape irrigation water is compliant
Proportion of Gross Floor Areas (GFA) meets non-potable water demand from alternative water sources	Grey or black water treatment plants (*e.g.* sewer mining) Points are awarded as function of GFA of buildings that have access to alternative water sources
Leak Detection – 1 point available	
Development to have site-wide water metering and monitoring for real-time leak detection	Must provide potable water meters for each building and must be connected to a real-time leak detection system Real-time leak detection system must have minimum hourly automatic assessment of supply and consumption Real-time leak detection system should include methods of messaging and alarming when leaks are detected

Comments

The first criterion applicable to the potable water consumption reduction is sound. The compliance requirement could be evolved to make better consideration of the reliability of supply and net potable water substitution achieved as opposed to the GFA criterion that seems more appropriate to building designs than community planning.

The leak detection criterion has a clear and sound intent: to make sure that in line with global best practice for water supply, ‘unaccounted for’ water (or system losses) are reduced and leaks detected. It is however difficult at the master planning phase of a project like West Belconnen or for consultants to be able to give any commitment about the future monitoring of the water network. This criterion may be better applied at a later stage of development and the adoption and ongoing operation of leak monitoring systems will be the prerogative of water utilities not developers.

2.5.4 Critical credit ENV-8 stormwater

Aim of credit

"To encourage and recognise projects that minimise the adverse stormwater impacts of urban development on receiving water bodies." (GBCA, 2013:227)

This credit assesses the modelling and management of stormwater runoff, stormwater evaporation or retention and effective treatment of stormwater. The aim of this credit is to achieve a flow regime and water quality that is close to the natural regime.

Credit criteria and compliance requirements

There are three criteria and up to three points that are on offer for this credit. The three criteria are:

- Volume: total annual stormwater runoff that is evaporated or retained within the community
- Pollution Reduction: More than 95% of total annual stormwater runoff is filtered or treated
- Frequency: Number of stormwater runoff days is 15 to 5 days greater than the natural annual runoff days.

The credit and compliance requirements for the criteria are summarised below in Table 8.

Table 8 **Green Star stormwater credit criteria and compliance requirements**

Criterion intent	Compliance requirements
Volume – 1 point available	
75% of total annual stormwater runoff to be evaporated or retained within the community via harvesting and infiltration (Partial points are provided for percentage of runoff that complies with criterion intent)	Utilise techniques for controlling water quality and flow regime thereby protecting receiving waters from degradation Volume management for slowing runoff rates and/or reducing total volume of water that impacts waterways Pollutant Management for treating pollutants in stormwater runoff
Pollution reduction – 1 point available	
Over 95% total annual stormwater runoff volume is filtered and treated before reaching stormwater system or receiving waters Under 5%(or less than natural state surface runoff) of volume of stormwater runoff runs untreated to stormwater system or receiving waters	Show that filtration systems treat the water to meet appropriate local or ANZECC (2000) concentration targets
Frequency – 1 point available	
Partial points awarded for number of stormwater 'runoff days' between 5 and 15 days greater than natural annual runoff days (the lower the number, the more points achieved)	Points calculated based on percentage of stormwater runoff days compared to natural runoff days

Comments

There are various issues with this credit with regard to the structure of points and compliance requirements. There appears to be confusion between volume of stormwater treated, as opposed to load reduction, and reference to local or ANZECC (2000) water quality guidelines where others could be just as valid. To elaborate, under the compliance requirements for 'Pollution Reduction' it states:

To be considered filtered and treated the project must show that all filtration systems treat the water to meet appropriate local or ANZECC (Chapter 3 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) concentration targets.

The issues associated with this requirement are:

- The ANZECC targets are for the monitoring of ambient or base flow conditions. Storm flow mobilises many substances through the process of wash off, and is unlikely to meets these "concentration targets". This applies even to runoff from natural catchments

- MUSIC is the software modelling package typically used in Australia to model stormwater runoff quality in order to demonstrate that WSUD and other measures can meet reasonable water quality objectives (and was utilised for this study). The default settings of MUSIC that are most commonly used throughout Australia have background discharge concentrations from stormwater treatment devices that are higher than the ANZECC concentration guidelines (for the reason noted above). Therefore, it is impractical to use MUSIC to demonstrate compliance with ANZECC.

Pollutant load reduction targets, such as those in the ACT WSUD Code, are the industry standard mechanism for assessing stormwater runoff quality and treatment. Load reduction targets refer to reduction in pollutant export from a development site as compared to an urban catchment with no water quality management controls. A more appropriate requirement to meet the same intent would be as follows:

Pollutant load reductions must meet or exceed the relevant local mandated or guideline targets applicable to the area of the development. For the ACT these targets are outlined in the ACT WSUD Code as:

- *Reduction in average annual suspended solids (SS) export load = 85%*
- *Reduction in average annual total phosphorus (TP) export load = 70%*
- *Reduction in average annual total nitrogen (TN) export load = 60%*

These were the targets adopted for this project, as the ACT WSUD Code exemplifies good practice in terms of meeting pollution reduction intentions. Under the documentation requirements for ‘Pollution Reduction’ it also states:

The evidence must demonstrate the median or other concentration levels of stormwater leaving the site demonstrating compliance with the relevant minimum levels. It must also state the quantity of stormwater discharge to be addressed by each stormwater treatment system (annually), and the sizing of all stormwater.

It is suggested that if the appropriate targets for pollutant load reduction are used, this requirement is no longer needed. In its current form it is ambiguous to refer to “median or other concentration levels”.

2.5.5 Relevant credit GOV-6 adaption and resilience

Aim of credit

“To encourage and recognise projects that are resilient to the impacts of a changing climate and natural disasters.” (GBCA, 2013:71)

This credit assesses a project’s resilience to the impacts of climate change and natural disasters by the development of a Climate Change Adaption Plan and a Community Resilience Plan.

Credit criteria and compliance requirements

There are two criteria each with two available points which make a total of four points for this credit. The credit and compliance requirements for the criteria are summarised below in Table 9.

Table 9 Green Star - Adaption and resilience credit criteria and compliance requirements

Criterion intention	Compliance requirements
Climate adaption – 1 point available	
Climate Change Adaption Plan to be developed in accordance with *ISO 31000:2009* and the AGO (2006) *Climate Change Risks and Impacts: A Guide for Government and Business*	Develop a Climate Adaption Plan with justifiable climate change scenarios Address minimum of two time scales for effects of temperature, precipitation, sea-level rise, relative humidity, drought/flood, wind, cyclones and bushfire as a minimum Risk identification to consider resilience of buildings, roads, public open space, electricity and communications infrastructure, hospitals, police, fire and ambulance stations The Plan is to be review and updated annually. Draft of plan to be provided to local council and emergency management authority for comment

Community resilience – 2 points available	
Community Resilience Report that addresses preparation, during and post disaster communication, safety and response, in accordance with the “Community Resilience Report Checklist for developers” developed by Green Cross Australia	Develop a Community Resilience Plan The Plan should align with local disaster management plans prepared by relevant district, Local Council or State and Territory authorities who have a regulatory responsibility for response to disasters and emergencies Draft of plan to be provided to local council and emergency management authority for comment

Significance of water management

Water cycle management that is inclusive of passive irrigation, WSUD, stormwater harvesting and reuse will have the potential of alleviating reliance on potable water resources, contributing towards increasing the relative humidity and lowering the daily maximum temperature. These key parameters of thermal comfort and health risks are typically problematic in urban environments particularly in association with urban heat island effect that is likely to be exacerbated by projected warmer summers. A more water sensitive city/community may form part of a broader community resilience plan or climate adaptation plan.

2.5.6 Relevant credit LIV-3 healthy and active living

Aim of credit

“To encourage and recognise projects that promote healthy and active living.” (GBCA, 2013:121)

This credit assesses a project’s holistic approach to designing active and healthy communities that lead to health benefits and promote active lifestyle.

Credit criteria and compliance requirements

There are three criteria and one minimum requirement for this credit with a total of five points available. The credit and compliance requirements for the criteria are summarised below in Table 10.

Table 10 Green Star - Healthy and active living credit criteria and compliance requirements

Criterion intention	**Compliance requirements**
Minimum requirement – footpaths	
Footpaths on at least one side of all streets with speed limits of 60 km/h and lower	Footpaths must comply with Austroads’ ‘Part 13: Guide for Traffic Engineering Practice, Pedestrians’
Active Transport – 2 points available	
Community to promote active lifestyle through good walking paths, cyclist facilities and the use of public transport	Signage to be installed that informs community of active lifestyle infrastructure including pedestrian and cyclist pathways, relevant speed limits, directional instructions and other relevant information Cycling and walking paths must be provided along routes (major and minor), connections to destinations and other networks Cycling and walking paths must provide solutions to all crossings, intersections, obstacles and parking All public transport interchanges must have secure, weather protected bicycle spaces All public transport interchanges must have an accessible covered shelter with a seat in accordance with the Disability Standard for Accessible Public Transport 2002

Recreational facilities – 1 point available	
Dwellings, places of employment and/or educational facilities are within close and easy access of a public park Dwellings, places of employment and/or educational facilities are within close and easy access of publicly accessible sports facilities relevant to the size and demographics of the community	All buildings must be within a radius of 500 m of facilities – can be increased to 1 km if active transport criteria is met Public parks must have fixed equipment relevant to the size and demographics of the community – parkland must be provided at a rate of 175 m^2 per every 1000 residents Examples of publicly accessible sports facilities include swimming pools, gyms, sports clubs, sports courts, bowling greens, golf courses, playing or athletic fields
Healthy places – 2 points available	
Development to be in line with holistic active and healthy living principles	The project must be designed to have achieved five key design outcomes as detailed in GBCA, 2013:124 The design must be in accordance with a planning tool specific to this issue. Two checklists that could be used include the NSW Government's 'Development and Active Living' or the Heart Foundation of Australia's 'ACT Active Living Impact Checklist' A project must comply with 75% of the checklists items to demonstrate compliance

Significance of water management

A water sensitive community will benefit from a well-structured and easy to access network of green infrastructure corridors which are supportive of pedestrian and cycling facilities and paths. The corresponding local and "water" parks can readily accommodate educational and recreational facilities. By carefully integrating the principles of WSUD, it is expected that a high quality public realm and healthier, more active place may be achieved.

2.5.7 Relevant credit LIV-4 access to fresh food

Aim of credit

"To encourage and recognise projects that provide access to local food production and distribution opportunities." (GBCA, 2013:129)

This credit rewards projects that provide access to fresh food by ensuring the community is close to fresh food retailers or gardens.

Credit criteria and compliance requirements

There are two criteria and two individual points available for this credit:

- Access to fresh food: fresh food is defined as food that is not preserved by canning, dehydration, freezing, smoking, or is not highly processed
- Local food production: a community food garden is defined as open space where residents or inhabitants have the opportunity to grow their own food

The credit and compliance requirements for the criteria are summarised below in Table 11.

Table 11 Access to fresh food credit criteria and compliance requirements

Criterion intention	Compliance requirements
Access to fresh food – 1 point available	
Dwellings, places of employment and/or places of education are close to a source of fresh food	Dwellings, places of employment and/or places of education must be within 1 km of a source of fresh food A source of fresh food is defined as a retail area, market or community garden, where at least 50% of its food offerings is fresh food

Local food production – 1 point available	
There are well sized, located, and serviced community food garden(s) within the community boundary	Dwellings, places of employment and/or places of education must be within 1 km of a community food garden – the garden must be within the boundary of the project A community food garden must be at least 150 m^2 ; community garden land must be no less than 100 m^2 per every 1000 residents in total across the project Compliant community gardens must answer the questions as detailed in Green Star – Communities PILOT, page 131 – they must be shown to be part of the community and be set up for future operation

Significance of water management

Food production constitutes a high demand of water. In order to achieve the stormwater management objectives which require significant volumes of stormwater to be harvested and reused, the opportunity of food production for disposal of the treated stormwater could be investigated and realised.

2.5.8 Relevant credit ECON-8 peak electricity demand

Aim of credit

“To encourage and recognise projects that reduce the need for electricity infrastructure augmentation to address growing peak electricity demand.” (GBCA, 2013:189)

The project will be compared against a business as usual peak electricity demand and will need to demonstrate that it achieves a peak load lower than 25% that of a typical community. This can be achieved by utilising fuel substitution, onsite generation or energy storage.

Credit criteria and compliance requirements

The credit and compliance requirements for the criteria are summarised below in Table 12. There is one point available for this credit that can be demonstrated by the meeting the ‘reduced peak electricity demand’ criterion. Otherwise, the point can be awarded by complying with one of the three “deemed-to-satisfy” criteria.

Table 12 Green Star - peak electricity demand credit criteria and compliance requirements

Criterion intent	Compliance requirements
Reduced peak electricity demand – 1 point available	
Peak electricity demand for the community is reduced by 25% when compared to a ‘business as usual’ case	A business as usual peak electricity demand should be established which considers all regulated energy initiatives The peak demand should be calculated to coincide with the peak in the vicinity of the project site
Deemed-to-satisfy: fuel substitution – potentially 1 point available	
All water heating, space heating and cooling for the community is powered with fuel sources other than grid electricity At least 25% of the annual energy needs of the project is provided by non-electric energy sources	None are specified, these are considered on a case-by-case basis
Deemed-to-satisfy: onsite generation – potentially 1 point available	
At least 30% of the annual electrical energy needs of the development are met through onsite power generation systems	None are specified, these are considered on a case-by-case basis

Deemed-to-satisfy: energy storage – potentially 1 point available	
At least 25% of the peak electrical demand is shifted to non-peak times through the use of energy storage systems	None are specified, these are considered on a case-by-case basis

Significance of water management

This credit focuses on energy sources substitution and peak energy demand reduction. Adopting extensive WSUD principles to designing the streetscape will offer opportunities to create a cooler urban environment with lower maximum daily temperatures and increase relative humidity which will reduce the energy requirements for air conditioning which can represent a major component of peak energy demand in Canberra.

2.5.9 Relevant credit ENV-2 ecological enhancement

Aim of credit

“To encourage and recognise projects that enhances the ecological value of the site.” (GBCA, 2013:99)

This credit rewards enhancement to ecological value and site biodiversity. This is achieved by submitting a Biodiversity Management Plan and by having a certified environmental practitioner assess the improvements.

Credit criteria and compliance requirements

There are two criteria and two individual points available for this credit. To confirm the condition of the site, scaled site plans or aerial photographs must be provided that show whether the site was greenfield or brownfield, footprints of any buildings and infrastructure, and evidence of site purchase. The credit and compliance requirements for the criteria are summarised below in Table 13.

Table 13 Green Star - ecological enhancement credit criteria and compliance requirements

Criterion intent	Compliance requirements
Change of ecological values – 1 point available	
The ecological value of the site is enhanced based on a comparison of the ecological attributes of the site at the date of site purchase and after build out	Partial points are awarded using the GBCA’s ‘change of ecological value’ calculator to compare the existing condition to the condition of the site after design/construction To confirm the presence of threatened/vulnerable species a check can be undertaken during the development application process that satisfies this criterion The site’s bioregion can be identified by accessing the relevant Australian Government websites
Biodiversity enhancement – 1 point available	
The development will create a significant net biodiversity gain representing a 20% improvement A Biodiversity Management Plan is prepared by a suitably qualified professional which demonstrates the long-term biodiversity values of the site	A significant net gain is defined as greater than 20% improvement and is determined by a suitable qualified professional A Biodiversity Management Plan must be developed by a suitably qualified professional, the plan is then provided to the local and state government department(s) for comment Mandatory or voluntary biodiversity offsets can be claimed but may only apply to residual impacts of development – this ecological assessment is undertaken by a suitably qualified professional

Significance of water management

There are two main aspects of water management relating to this credit:

- By adopting an extensive WSUD strategy and ‘green infrastructure’ approach to the public open space, nature reserves and WSUD assets, it will be easier to deliver on key environmental challenges that are the connectivity of habitats and populations and improved resilience
- Unless the urban stormwater excess generated from the urbanised site is adequately management the drainage gullies in the Murrumbidgee River corridor will be exposed to high risk of scour and erosion which would impede any environmental enhancement efforts and would create significant barriers across the corridor.

2.5.10 Relevant credit ENV-3 heat island effect

Aim of credit

“To encourage and recognise projects that reduces heat island effect.” (GBCA, 2013:207)

This credit assesses mitigation of heat island effect within the urban environment. This is achieved by incorporating vegetation, water bodies, and/or lightly coloured parking lots, roads, sidewalks, plazas or roofs.

Credit criteria and compliance requirements

The credit and compliance requirements for the criteria are summarised below in Table 14.

Table 14 Green Star - heat island effect credit criteria and compliance requirements

Criterion Descriptors	Compliance Requirements
Heat island effect	
At least 50% of the total site area in plan view comprises vegetation, roof materials having a minimum solar reflective index (SRI) of >78, unshaded hardscape having a SRI of >29, water bodies and water courses	Vegetation is defined as landscaped areas, parkland, green space and trees. Unshaded hardscape is defined as hardware that is not shaded by vegetation and includes roads, plazas, paths and open unshaded car parks Water bodies and permanent water course areas are measured from the highest natural level

Significance of water management

By adopting a green infrastructure approach to the management of stormwater and provision of public open space, there is a high potential for WSUD to support mitigation efforts against urban heat island effects.

2.5.11 Relevant credit INN-1 innovation

Aim of credit

“To encourage and recognise projects that adopt innovation in planning, design and delivery of communities.” (GBCA, 2013:261)

Points awarded for this credit are at the discretion of the GBCA and can be claimed for up to ten innovation initiatives across the one credit, *i.e*. ten points are available. There is no limit to the number of innovations claimed or the number of categories each innovation can claim from.

Credit criteria and compliance requirements

There are five criteria that a maximum of ten points can be claimed against for this credit. The credit and compliance requirements for the criteria are summarised below in Table 15.

Table 15 Green Star - innovation credit criteria and compliance requirements

Criterion intent	Compliance requirements
Innovative process or technology	
A sustainable performing process, methodology and/or technology that is considered a ‘first’ in Australia or around the world	Must be able to demonstrate that the innovation is an Australian first or world first
Market transformation	
Substantially contributes to the broader market transformation towards sustainable development in Australia or in the world	Must transform the market and result in new ways of approaching, applying or achieving sustainable outcomes
Improving on Green Star benchmarks	
Substantial improvement to an environmental, social or economic impact addressed by the Green Star credit	To be eligible, the project must achieve full points for the particular credit that it is applying for and then demonstrate that the environmental, social and/or economic benefit is over and beyond the Green Star benchmark
Green Star challenges	
Respond to the *Green Star – Communities Innovation Challenges* posted on the GBCA innovation portal	The project must abide by the conditions of the challenge as outlined in the GBCA innovation portal
Exceeding the scope of Green Star	
Address an issue that is not covered within any of the existing Green Star Credits or *Green Star – Communities Innovation Challenges*	The environmental, social and/or economic innovation must be quantifiable, be beyond ‘best practice’ in the Australian context and be related to the planning, design and construction of communities (not performance)

2.6 Objectives and targets for West Belconnen

The integrated water management strategy and infrastructure response for West Belconnen needs to fulfil a number of objectives and targets to meet the sustainability, feasibility, replicability and exemplarity requirements as set out by The Riverview and the ACT Land Development Agency. The West Belconnen project has indeed adopted voluntary objectives in addition to the current regulatory framework in the ACT and NSW.

2.6.1 Summary of regulatory and voluntary objectives

The integrated water management strategy and associated infrastructure response need to address a series of criteria, in response to the following frameworks:

Regulatory requirements and guidelines

- *ACT Water Act 2003*
- *Think Water, Act Water:* ACT Water Strategy (ACT Government, 2004)
- ACT *Water for the Future – Striking the Balance*: ACT Water Strategy (ACT Government, 2014)
- ACT *Design Standards for Urban Infrastructure*[13]
- ACT WSUD Code
- *NSW Water Management Act 2000*

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[13] Accessible at http://www.tams.act.gov.au/city-services/Development_Approval_and_Applications/development_applications/design_standards_for_urban_infrastructure, accessed September 2014

- *NSW Water Act 1912*
- NSW BASIX[14]
- NSW *Integrated Water Cycle Management Guidelines for Local Water Utilities* 2004
- *Australian Drinking Water Guidelines* (NHMRC, 2011)
- *Australian Water Recycling Guidelines* (NHMRC, 2006).

Leading innovative design

The study team has further ensured that leading and innovative water management approaches have been brought to this study by:

- Consulting and embedding requirements of *Green Star Communities – PILOT* scheme criteria and credits
- Undertaking a review of international and Australian modern practices
- Promoting and influencing other design and planning consultants to integrate water sensitive principles in the urban design and overall community master plan
- Closely collaborating with the landscape architect (Macgregor Coxall) to integrate POS, WSUD measures and green infrastructure.

Minimise intervention to the landscape

- Minimise the infrastructure requirements
- Minimise the need for earthworks and adjustments to the natural landscape (*i.e.* work with the site).

Low environmental footprint

- Avoid impact on the visual amenity of the Murrumbidgee River corridor by mitigating (as far as practical) the need for water transfer infrastructure down the escarpment to the river
- Avoid erosion and other detrimental impact on the drainage line through the escarpment of the Murrumbidgee River corridor
- Restrict impact on environmental value (flora, fauna habitats and sensitive species).

2.6.2 Specific targets: the ACT WSUD Code requirements

The ACT WSUD Code guides the setting of development objectives for urban runoff quantity and quality.

Water quantity

Water flow rates can be managed with the use of flood retarding basins designed for specific criteria, as set out in Table 16. These targets require peak flows to be attenuated to pre-development levels but do not require the increase in urban runoff volume (the urban excess) to be reduced.

Table 16 Performance targets for stormwater quantity

Principle	Target
Reduction of runoff peak flow to no more than the pre-development levels and release captured flow over a period of 1 to 3 days	3 month Average Recurrence Interval (ARI)
Reduction of peak flows to pre-development levels	5 year to 100 year ARI

Water quality

To meet the water quality targets, a stormwater treatment train approach is required. This may consist of gross pollutant traps, filter strips, swales, bioretention systems, constructed wetlands and ponds. The responsibility for meeting targets on development or redevelopment sites lies with the developer, while responsibility for meeting the regional or catchment-wide targets lies with the ACT Government. In the case of the West Belconnen development, the regional targets have been adopted for the development as a reflection of what constitutes good practice in Australia in terms of water quality policy objectives. As well, it recognises the absence of any opportunities for the ACT or NSW governments to construct measures downstream of the urban development before urban runoff discharges to Ginninderra Creek or the Murrumbidgee River. These targets refer to reduction

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[14] BASIX = ‘Building Sustainability Index’, see: https://www.basix.nsw.gov.au/basixcms/, accessed September 2014

in pollutant export from the proposed development compared to an urban catchment with no water quality management controls. The targets are set out in Table 17.

Table 17 Targets for stormwater quality management

Principle	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 %

Potable water reduction

The WSUD Code identifies demand reduction measures such as low water-use landscapes, and water-efficient fixtures and appliances. The provision of alternative supplies for non-potable demands is recommended using a “fit for purpose” approach. The Code’s target for mains water use reduction is 40% (compared with 2003 water usage levels) in all new developments and redevelopments. The intent may be achieved with:

- Stormwater harvesting and/or wastewater re-use
- Water efficient fixtures being fitted to all commercial, industrial and residential buildings

Additional potable water demand reductions can be brought about by landscaping in public open space and in domestic gardens that minimises irrigation requirements.

2.6.3 Specific targets: ACT Standards and Codes for Urban Infrastructure

All developments need to comply with these codes and standards:

- The *ACT Territory Plan* guides development within the ACT. It stipulates that all development must comply with the requirements of the ACT WSUD Code
- *Design Standards for Urban Infrastructure* are produced by Territory and Asset Management Services (TAMS). These standards guide the design of infrastructure that may be used to manage water, such as roads, stormwater drainage networks, urban open space, and urban wetlands and ponds, but do not guide treatment targets. They stipulate:
  - In the residential areas: drainage network to be designed to accommodate 5 year ARI storms, the larger storms up to 100 year ARI have to be contained within the road corridor or prescribed drainage easements
  - In the higher density areas of group centres, the capacity of the network is increased to 10 or 20 year ARI. Road corridors constitute the preferred drainage network for large storms.

2.6.4 *Green Star - Communities* objectives

The water management objectives adopted for the West Belconnen project were strongly driven by the *Green Star - Communities* assessment criteria, which have been adopted for the overall master planning of this project. For a detailed review of the Green Star criteria, please refer to Section 2.5. The relevant criteria for water management provide more stringent environmental objectives than those set in the ACT WSUD Code. The relevant water management criteria are:

- *Stormwater runoff volume reduction (75%)* – the reduction applies to the post development runoff
- *Frequency of runoff (maximum 15 to 5 days greater than natural runoff)* - the ‘natural runoff’ as prescribed by the *Green Star - Communities* methodology was estimated as 6 days. This sets a target for the project at 11 days for maximum points to 21 days for some points.
- *Pollutant reduction (95% treated)* - in practice this is similar to the ACT WSUD Code requirements for pollutant reduction, and so meeting these was considered adequate against this GBCA criterion
- *Provision of alternative water sources to meet all non-potable water demand (%)* – opportunities for utilising alternate water sources at West Belconnen were explored.

2.6.5 Performance reporting

The performance of the scenarios considered was reported on each of the key criteria relating to water management and were summarised in 'score cards' which specifically reported on the following criteria:

- Total annual runoff volume reduction [target: 75%]
- Number of runoff days [target: 11 to 21 days]
- Peak flow attenuation [target: pre-development for 2 year to 100 year Average Recurrence Interval]
- Gross Pollutant load removal [target: 90%]
- Total Suspended Solids load removal [target: 85% for each sub-catchment]
- Total Nitrogen load removal [target: 70% for each sub-catchment]
- Total Phosphorus load removal [target: 60% for each sub-catchment]
- Potable water substitution [target: maximum achievable with minimum of 40%].

An example of such a 'score card' is presented below. Additionally, cost estimates of the supporting infrastructure were prepared.

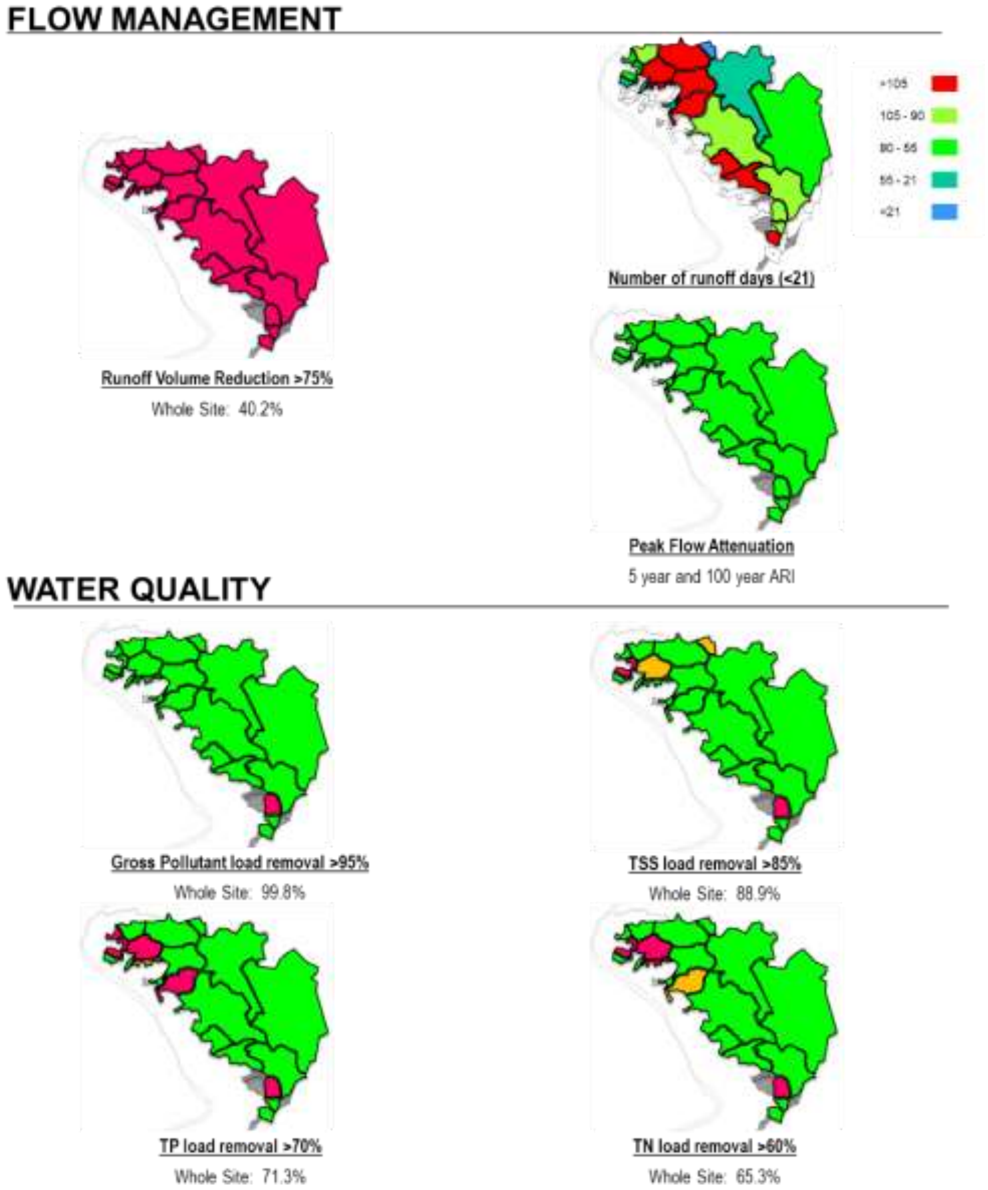


Figure 21 Example environmental outcomes score card for the West Belconnen water sensitive community strategy scenarios

3.0 The Master Plan for West Belconnen

3.1 Key drivers

This section of the report presents the integrated water management strategy and the corresponding infrastructure that most wholly complies with the adopted sustainability criteria and objectives. Within the constraints of the local site and working with the overall structure plan for the site (Appendix c), it is geared toward maximising:

- Potable water substitution
- Reduction in urban stormwater excess
- Stormwater harvesting to reduce impact of urbanisation
- Protection of the Murrumbidgee River corridor gullies and Ginninderra Creek riparian corridor, and mitigating the need for water transfer infrastructure being placed in the corridor
- Exceedance of the ACT WSUD Code requirements
- *Green Star - Communities* points.

3.2 Evaluating the proposed master plan

To enable an assessment of the performance of the proposed ‘aspirational’ master plan, a ‘base case’ and an ‘intermediary’ water management arrangement were also developed. The ‘base case’ aimed simply at meeting the ACT WUSD Code and other regulatory requirements, while the ‘intermediary’ arrangement was the same as the base except that it included some stormwater harvesting and reuse infrastructure that is more commonplace in Canberra than what is proposed in the ‘aspirational’ arrangement.

Each scenario had an environmental scorecard, Green Star points scoring potential assessment, and delivery cost estimate prepared, to enable a preliminary comparison of benefit and costs.

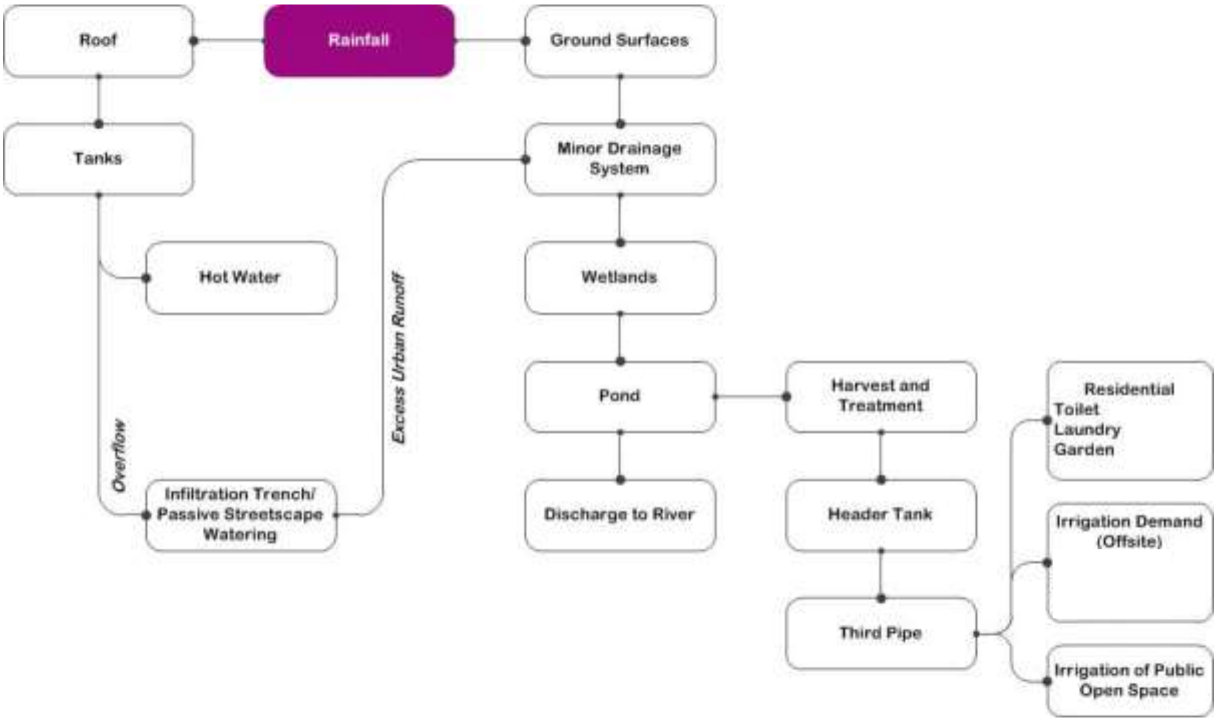
3.3 The ‘aspirational’ proposal

3.3.1 Proposed water cycle

The site water balance modelling carried for the site has revealed that with the proposed development of the site, a significant increase in urban stormwater runoff is to be expected. Under current site conditions (pastures), the total annual runoff from the West Belconnen proposed urban area is in the order of 1,100 ML *per annum*. With the proposed urban development, the potential increase in imperviousness is directly responsible for a significant increase in total annual runoff volume to approximately 3,100 ML per annum (+180%).

With the core objectives of flow volume management and reduction in both total runoff volume and flow days, the proposed water cycle includes significant stormwater harvesting initiatives. The proposed water cycle is depicted in Figure 22 in the following page.

Figure 22 Proposed integrated water cycle for West Belconnen



The fundamental components of the proposed WSUD master plan include:

- Rainwater harvesting at a household level for hot water supply: allocating the ‘cleanest’ portion of the precipitation to the end use requiring the best water quality (noting that some water quality management interventions may be required to satisfy health risk provisions, as discussed at Section 3.3.3)
- Opportunistic streetscape WSUD measures: the proposed ‘*biostreets’* (Appendix c) including WSUD measures in the streetscape will be beneficial to both water quality and quantity outcomes as well as other objectives of the project including liveability, resilience and marketability. It is too early to adequately quantify and firm up dependable assumptions with respect to provisions in the streets, so the proposed strategy does not rely on those to meet the objectives
- Stormwater is collated in a series of large distributed wetlands and ponds which have been sized to meet the water quality objectives of the development: The wetlands are primarily delivering water quality improvement. The ponds, more adaptable to include stormwater harvesting infrastructure and accommodate water level fluctuations, form the ‘backbone’ of a proposed centralised stormwater harvesting scheme (see next point)
- A centralised stormwater harvesting scheme with complete water filtration and treatment plant supplying water throughout the residential areas via a ‘third pipe’ network similar to recycled water schemes as well as for additional potential demands including urban food production and off site irrigation demands (*e.g.* golf courses, sports facilities and school precincts)
- Stormwater in excess of the harvesting capacity such as during storm events is buffered in the detention capacity provided in the ponds and wetlands and is discharged at pre-development peak flows to the existing natural drainage gullies and to the Murrumbidgee River and Ginninderra Creek.

3.3.2 Major infrastructure requirements

The proposed WSUD master plan will require a range of assets at various scales to enable the capture, treatment, slow release, harvesting, filtration, storage, distribution and safe reuse of water resources on site.

The major infrastructure has been developed to pre-feasibility study level and is documented in the drawing set (under separate cover) entitled *‘West Belconnen WSUD’ Ref. 60308190-DRG dated September 2014* (from hereon referred to as “the WSUD drawing set”).

The infrastructure master plan was developed based on the February 2014 version of the overall structure plan by architects Roberts Day presented in Appendix b. It is important to note that the structure plan was subsequently updated with the final structure plan released in June 2014 (Appendix c).

The final structure plan has progressed and evolved from the February 2014 version. Upon review, it is important to note that the fundamental assumptions underpinning the WSUD master plan did not require updating. The parameters verified included:

- Density and lot numbers
- Location and zoning of densities
- WSUD provisions and location of WSUD measures
- Imperviousness assumptions.

Cut-off drains

A network of cut-off drains has been included in the infrastructure. The requirement for cut-off drains will depend on the treatment of the urban edges, the presence of edge roads and any access tracks for firefighting, *etc*. They provide a key role in mitigating higher flows from progressing down the Murrumbidgee River corridor. Importantly, it will be necessary to capture and divert stormwater flows from some sub-catchments to centralised measures such as ponds and wetlands. Given the marked topography of the site, this will be particularly important to reduce the number of ponds and wetlands required (see next section). The actual need for cut-off drains will depend on the extent and nature of the blocks and road network in the vicinity of the river corridor.

Ponds and wetlands

The stormwater infrastructure for West Belconnen includes a number of interconnected ponds and wetlands that combine to attenuate peak flows, treat stormwater before discharging to the environment, and facilitate the stormwater harvesting.

The typical treatment train for West Belconnen would rely on the following:

- Rainwater tank and reuse at the household level
- Stormwater discharge to kerb (as opposed to underground drainage network)
- WSUD measures in the street (where appropriate and feasible – refer ‘biostreet’ concept provided in Appendix d)
- Treatment wetlands (typically 4% of its catchment area). Each treatment wetland would include provisions for trash rack or other Gross Pollutant Trap (GPT), a sedimentation inlet basin and planted macrophyte area
- Ponds (typically 1% of its catchment area). Given the steep topography of the site, it is not possible to combine all services from WSUD assets in a centralised or ‘single’ location as is often done in the ACT. This means that the stormwater peak flow attenuation will be provided in a separate basin or pond. The ponds will be designed to accommodate a larger water level variation and will be adequately designed to maximise amenity values
- For low flows management: stormwater harvesting scheme for reuse in irrigation or via ‘third pipe network’ to homes.

Stormwater harvesting ponds

From the approximately 1,200 ha of land to be developed, the stormwater harvesting scheme extends to a little over 1,000 ha through the provision to residential areas of treated stormwater. The extent of stormwater harvesting has been consolidated to minimise the infrastructure necessary and maximise the reliability of supply and environmental benefits associated with the harvested volumes.

There is a total of 41 large (area in excess of 2,000m^2) regional ponds and wetlands as well as 19 smaller measures (area less than 2,000m^2) across the West Belconnen site. This represents an average catchment area of 29.1 ha per regional measure or 19.9 ha for every WSUD measure. Such values are in line with provisions under current ACT and Australian practice.

The total volume of earthworks to complete the dam embankments is approximately 145,000 m^3. In comparison the Enlarged Cotter Dam represents approximately 650,000 m^3 (4.5 times)[15].

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[15] ACTEW Corporation (2009), *Enlarged Cotter Reservoir and associated work*, Development Application

Stormwater pump stations

In order to transfer the stormwater to the storage tanks and treatment plant, a series of 17 pump stations will be required. Each pump station will include a sand filter for removing the coarser sediment to limit the risk of fouling of the pipes and preserve the long term performance of the harvesting scheme.

Pump stations include a housing building, three pumps: two duty pumps and one on standby (for failure and maintenance) and they have provisionally been designed for a managed maximum flow rate of 60 L/s with a maximum static head estimated at 52 m for the stations located at the lowest level in the Murrumbidgee River corridor.

Stormwater harvesting raising mains

A network of stormwater raising mains connects the various stormwater harvesting ponds to the raw water storage area. There are six major branches to the network, harvesting water from both the Murrumbidgee River and Ginninderra Creek sub-catchments of the site.

For the purpose of this pre-feasibility study, the raising mains are designed as 150-225 mm diameter PVC-U pipes with non-return valves required at the various junctions of the network. There is a total of 13.6 km of raising mains to deliver the stormwater harvesting scheme.

Raw stormwater tanks

Under *Australian Water Recycling Guidelines* ([AGWR] NHMRC, 2006), there is a requirement to provide a storage capacity equivalent to 3 days' of consumption, for supply redundancy in the event of failure. Based on the estimates for maximum daily demand between 1.8 ML and 2.5 ML per day (depending upon the season), this means that the stormwater harvesting scheme needs to include no less than 7.5 ML of storage. At West Belconnen, this security of supply to homes is also achieved by having potable water available as a backup in the event of a loss of treated stormwater supply.

The infrastructure master plan includes 8 ML of storage (listed as 'Tank Farm 1' in the WSUD drawing set) located at the landfill site. For this study, it is assumed that the storage would be best provided as a corrugated iron 'tank farm' to offer greater cost effectiveness and improved flexibility for integration within the future site uses for the present landfill site on the development area. This would be done using eight (8) tanks of 1 ML capacity.

There are several possible products on the market that would be suitable, but an example would be the 'Rhino Tank – RT720' which is 3m high (and can be buried) and 20m in diameter.

Stormwater treatment plant

The primary treatment consideration is to remove microbial agents from the stormwater that have the potential to cause harm and illness in humans to levels that pose a low health risk. The *AGWR* provides guidance on the types of treatment solutions that may provide appropriate treatment for various applications. On consultation with the guidelines it is likely that an in-line coagulation + dual media sand filtration + UV disinfection will be required to enable the stormwater to be taken into homes via a third pipe. Similar to what is required in many potable water systems, chlorine dosing and maintenance of a residual may be necessary as well.

Treated stormwater tanks

As previously mentioned the requirement to have 3 days' worth of water supply in storage means that the stormwater harvesting scheme requires an 8ML storage capacity for treated (distribution ready) non potable water. As for the raw stormwater tanks, it is proposed that this is best done using a tank farm of eight (8) 1ML capacity tanks. It is worth noting that the tank farm solution also offer the additional benefit of being able to stage the construction of the tanks to match the staging of the urban development.

Third pipe network including booster pump

Given the high level of analysis and planning for the project, it is not possible for the dual reticulation (or third pipe) network to be planned and designed. It would be necessary to confirm the configuration of the entire road network including local streets to be able to quantify with adequate accuracy the actual reticulation network. For the purpose of this pre-feasibility study, it is suggested that a non-potable water network to households would be very comparable to the potable water network, both in terms of lay-out, structure, sizing and cost.

The provisional infrastructure allowance is therefore based on the potable water network provisions which were determined by Brown Consulting and provided to this study team, and that were based on recent past development projects in the ACT in North Canberra/Gungahlin[16].

The non-potable water reticulation network hence includes:

- water pipes including trunk and distribution
- water fittings
- stop valves
- hydrants and tees
- end caps
- concrete works
- ties.

The storage and header tanks for the non-potable water supply are located at the landfill site at around Relative Level (RL) 573.0 m. This means that most of the site can be supplied by gravity from the storage tanks. Areas that would be supplied by gravity include the north and east portions of the site as well as most of the Murrumbidgee Corridor interface. The south east portion of the site, located above RL 573.0 m cannot be supplied by gravity and requires the installation of a booster pump.

3.3.3 At a household level

The proposed water management strategy implies a number of measures at the household level which are described below.

100% roof capture

In the ACT, it is prescribed under the ACT WSUD Code and the respective building codes that a minimum of 50% of the roof area is to be connected to rainwater tanks. Here it is proposed that the entire roof area be harvested. The changes to building code and construction industry practices are minimal but would significantly improve both the reliability and benefit to the householder of onsite rainwater harvesting.

Charged downpipes

In association with the 100% roof capture, it will be necessary for buildings to adopt ‘charged’ downpipes, rather than free draining ones. This will represent a negligible change to construction practices and cost, it will be important to ensure that all built forms can maximise the rainwater harvesting potential.

Rainwater tanks

It is proposed that rainwater tank be made compulsory at West Belconnen. With the proposed ‘rainwater to hot water’ approach, and with using treated stormwater for other non-potable uses, the tank sizes at the home can be reduced as compared to the more common scenario of using rainwater for irrigation, laundry and toilet flushing. Preliminary findings are that 2 kL tanks would suffice for an average household of 2.6 people for the situation where rainwater is used for hot water systems only, and a ‘third pipe’ to the home for other non-potable needs. The currently predominant tank size in the ACT is 3 kL.

Hot water systems

A variety of options for rain-to-hot water systems that can accommodate the need to heat water to 60 degrees and then be mixed with cold water supplies to alleviate the temperature to < 50°C (for safety reasons) were provided earlier (Section 2.4.5).

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[16] An additional provision of 10% was included to Brown’s cost estimates and applied as a ‘third pipe’ network estimate to account for additional valves and other network components that may be required to prevent backflow and provide a higher level of control and security on water distribution.

3.4 'Base' and 'intermediary' system arrangements

The proposed 'aspirational' strategy for integrated water management at West Belconnen delivers particularly highly in terms of environmental outcomes and the key performance criteria as adopted for this study (Section 2.6).

To enable the adequate appreciation of the benefits of the strategy, it is important to establish the performance against a baseline scenario. For this purpose a 'base case' was developed which relied on incorporating the common urban development practice in the study area regions. Additionally, an 'intermediary' case was developed that was effectively the base case with the incorporation of a smaller scale stormwater harvesting and use system for POS irrigation, as is in place in various parts of the ACT already. Both of these are presented below.

3.4.1 'Base case' scenario

The basis for the 'base case' water cycle management is well established. Since the introduction of the ACT WSUD Code in the late 2000s, there have been a number of suburbs planned and constructed which have applied the rational and underpinning principles of the code.

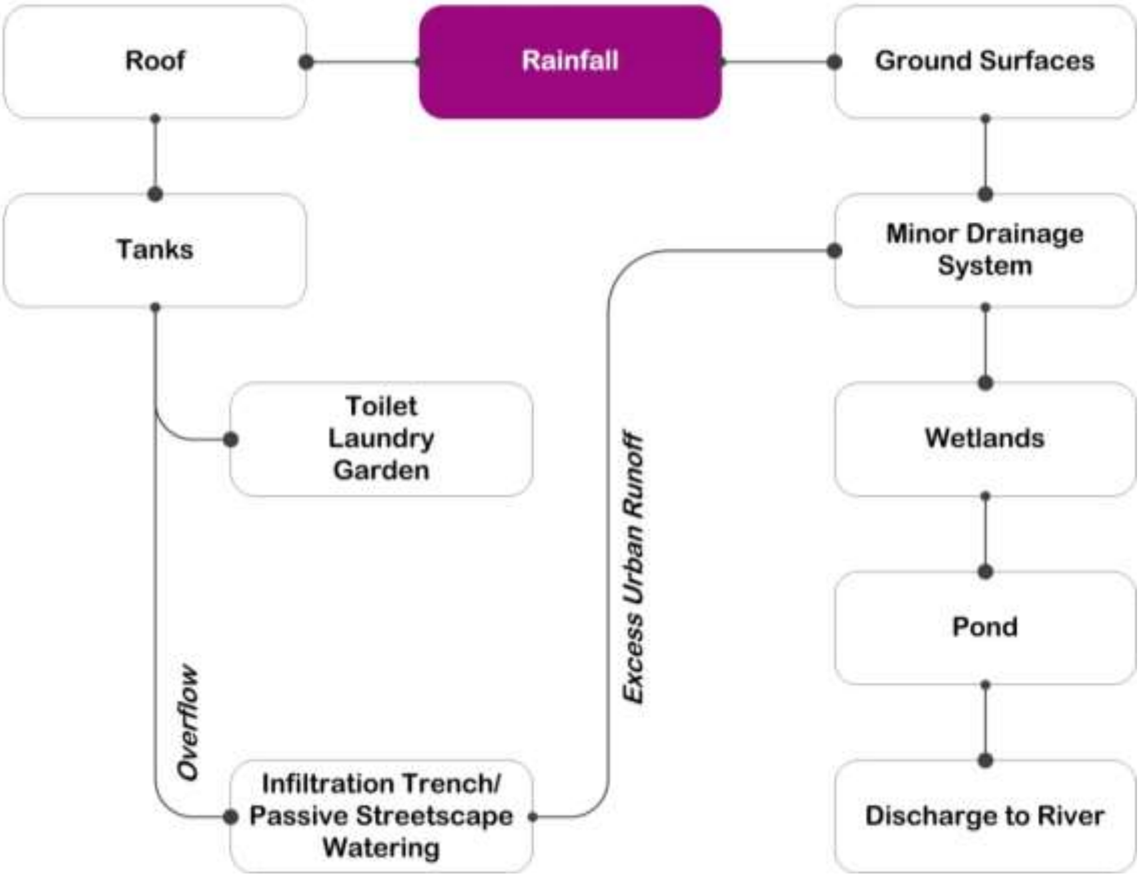
The 'base case' water cycle management involves:

- Rainwater harvesting at a household level for non-potable uses
- Rainwater tanks (typically 2-3 kL per block in excess of 300 m^2)
- Occasionally distributed WSUD measures in the streets (as per Appendix d)
- Regional WSUD measure (either wetland, pond, or a combined asset)

Figure 23 Business As Usual WSUD in the ACT: Springbank Rise (Casey) (Photo: J Lepetit, August 2013)

The 'base case' water cycle management is represented on the following page.

Figure 24 'Base' water cycle



As there is no possibility for regional stormwater quality management measures downstream of the development site, it was considered that the ACT WSUD Code 'regional' targets would again be applicable to a 'base case' development. As a starting point, the wetlands and ponds layouts from the 'aspirational' case were adopted and tested (using MUSIC modelling) to determine how adequately these measures would be able to meet ACT WSUD Code requirements for quality and flow management. If necessary, the pond and wetland layout and sizing would be amended to satisfy the WSUD Code targets. The key findings of the investigation are that:

- The number of ponds and wetlands remains the same as for the 'aspirational' case as they are determined by the topography of the site and the numerous discharge points to Ginninderra Creek and the Murrumbidgee River
- While there is small potential for some further consolidation of the various WSUD measures along the Ginninderra Creek interface, it would require further detail on the fine regrading of the site to establish the feasibility of doing this. In addition it would only represent the elimination of 3 to 4 measures at the most
- In most instances, the dimensions of the various ponds and wetlands are primarily dictated by the water quality targets which are consistent between the 'base case' and 'aspirational' strategies. There is potential for a reduction of the area for the various ponds and wetlands, but this would be rapidly impinged by the flood attenuation requirements
- At a household level, there would be no difference for most blocks as the rainwater tank provisions are identical under both schemes (capacity of 2-3kL).

Consequently, it can be reasonably considered that the wetlands and ponds provisions under both 'base' and 'aspirational' scenarios are the same. The absence of the stormwater harvesting, 'third pipe' and 'rain-to-hot' water systems differentiate the 'aspirational' and 'base' cases.

3.4.2 'Intermediary' scenario

Having established the primary wetlands and ponds layouts were the same under the 'base' and 'aspirational' cases, the features that underpinned the 'intermediary' scenario were:

- Retaining the wetlands, ponds and bioretention system layouts to achieve the mandated water quality and flow management requirements
- Elimination of the 'third pipe' network to households (as per the 'aspirational' case) and a reduced reliance on stormwater harvesting to enable smaller, decentralised harvesting and irrigation systems (primarily to manage the site water balance and control flows), noting there are several examples of similar systems in place in the ACT and NSW.

The proposed 'intermediary' water cycle is illustrated in Figure 25 below.

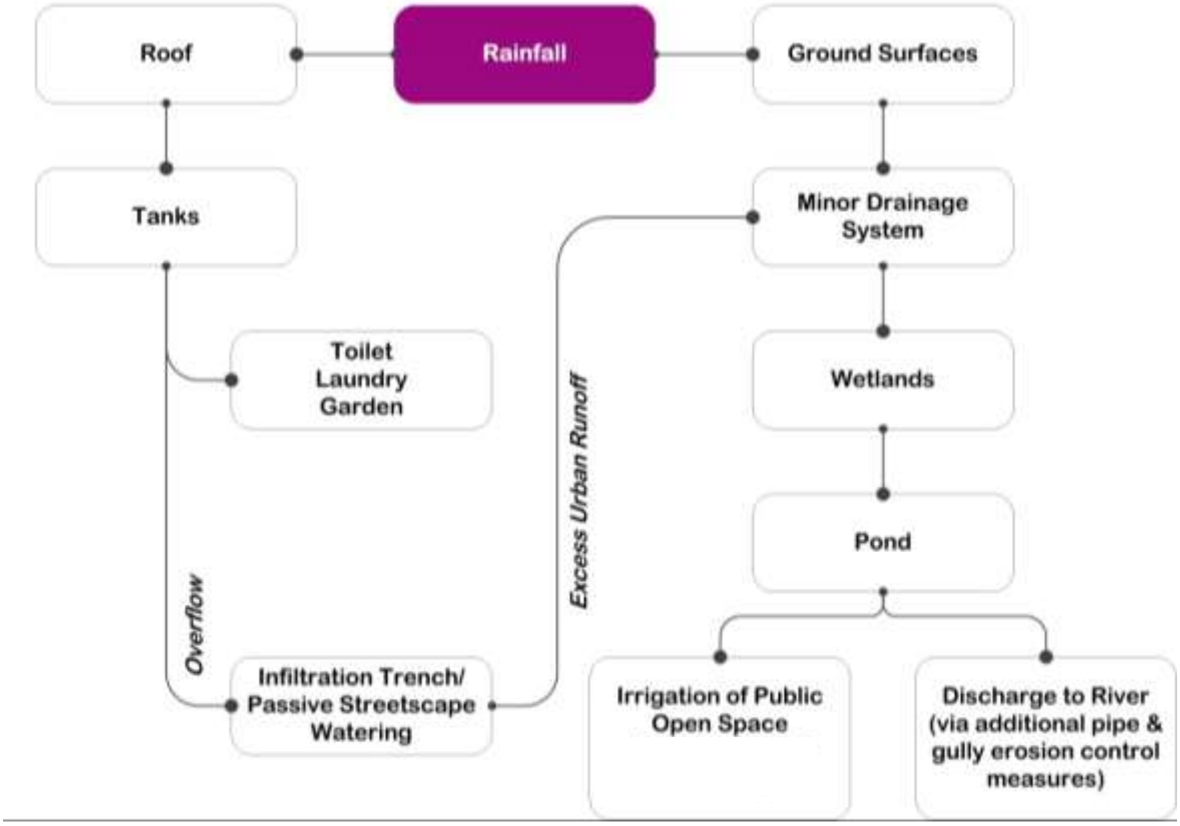


Figure 25 'Intermediary' scenario water cycle

The necessary infrastructure to deliver the 'intermediary' strategy includes:

- The number of ponds and wetlands remains the same as for the 'base' and 'aspirational' cases as they are determined by the topography of the site and the numerous discharge points to Ginninderra Creek and the Murrumbidgee River
- At a household level, there would be no difference for most blocks as the rainwater tank provisions are identical under both schemes (capacity of 2 to 3kL max.)
- Pump stations at 12 harvesting locations equipped with sand filters

3.5 Performance comparison

Each of the scenarios developed comply with the basic requirements of the ACT WSUD Code and with other water and environmental management needs of ACT, NSW and the Commonwealth as they relate to water quality and flow management. To differentiate the scenarios, there are three primary measures that have been developed through this study:

- Environmental (water flow and quality) performance
- Potential contribution to the *Green Star - Communities* point scoring

- Infrastructure delivery costs.

These outcomes can assist to make decisions about what aspects of either scenario presented may be pursued and further defined during more detailed design stages.

3.5.1 Environmental score cards

The score cards visually summarise the performance against the key flow management and water quality objectives for the project across the nearly 50 sub-catchments. For most criteria, a simple traffic light indicator system was used for each sub-catchment

Table 18 Environmental performance score cards – legend (for interpreting Figure 26 - Figure 28)

Colour	**Interpretation**
Traffic light system for water quality performance	
Green	The criterion is met or exceeded in that sub-catchment
Orange	The performance is within proximity, though not meeting, the criterion
Red	The criterion is not met
'Run off days' colour coding	
Blue	Less than 21 runoff days per year: *Green Star – Communities* points guaranteed
Dark green	21 to 55 runoff day: over 50% reduction on runoff days, *Green Star – Communities* points defensible
Lighter greens	55 to 105 run off days: reduction in runoff days is less than 50%
Red	Over 105 runoff days – there is no reduction in run off days achieved.

Table 19 Environmental performance comparison for water management scenarios

Outcome	**'Base'**	**'Intermediary'**	**'Aspirational'**
Stormwater volume reduction	40.2%	46.2%	55.7%
Runoff days (range across various sub-catchments)	55-120 days	20 -105+ days	20-90 days
Peak flow attenuation for 1 in 2 and 1 in 100 year flows	yes	Yes	yes
Reduction in Gross Pollutants Loads emanating from site	99.8%	99.8%	99.8%
Reduction in Suspended Solids Loads emanating from site	88.9%	89.4%	90.6%
Reduction in Total Phosphorus Loads emanating from site	71.3%	73.6%	78.1%
Reduction in Total Nitrogen Loads emanating from site	65.3%	68.4%	72.7%
Potable Water Substitution	27%[1]	~30%	36%
Scour potential on Murrumbidgee River drainage gullies (relative amongst the three scenarios)	Higher – could require extensive collection and piping of excess flows down the corridor	Moderate – managed through corridor protection and intervention measures	Lower – excess flows managed through onsite WSUD and stormwater harvesting measures

Table notes: 1. Rain water tanks are providing the stated potable water substitution.

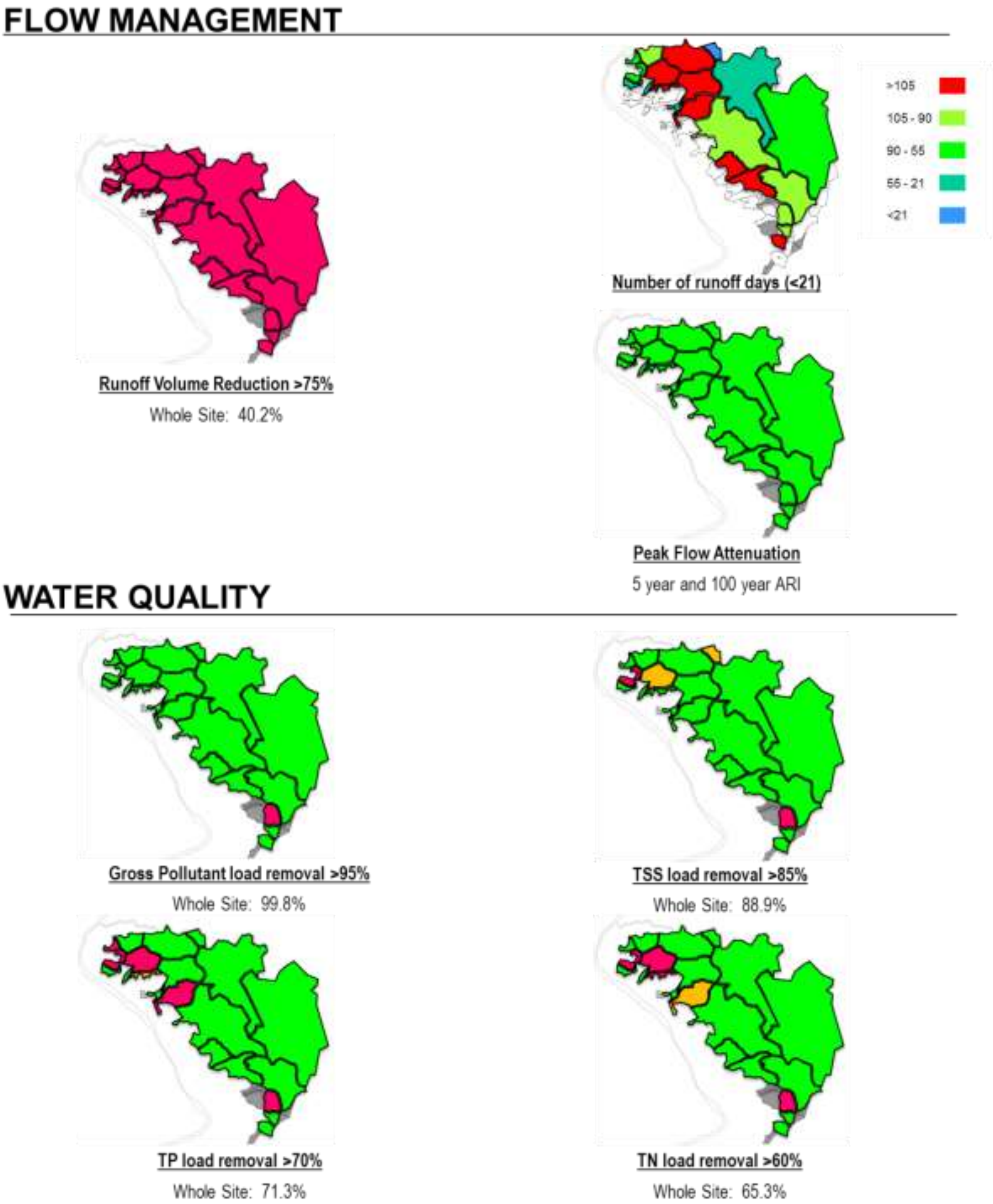


Figure 26 Environmental performance scorecard – 'base case'

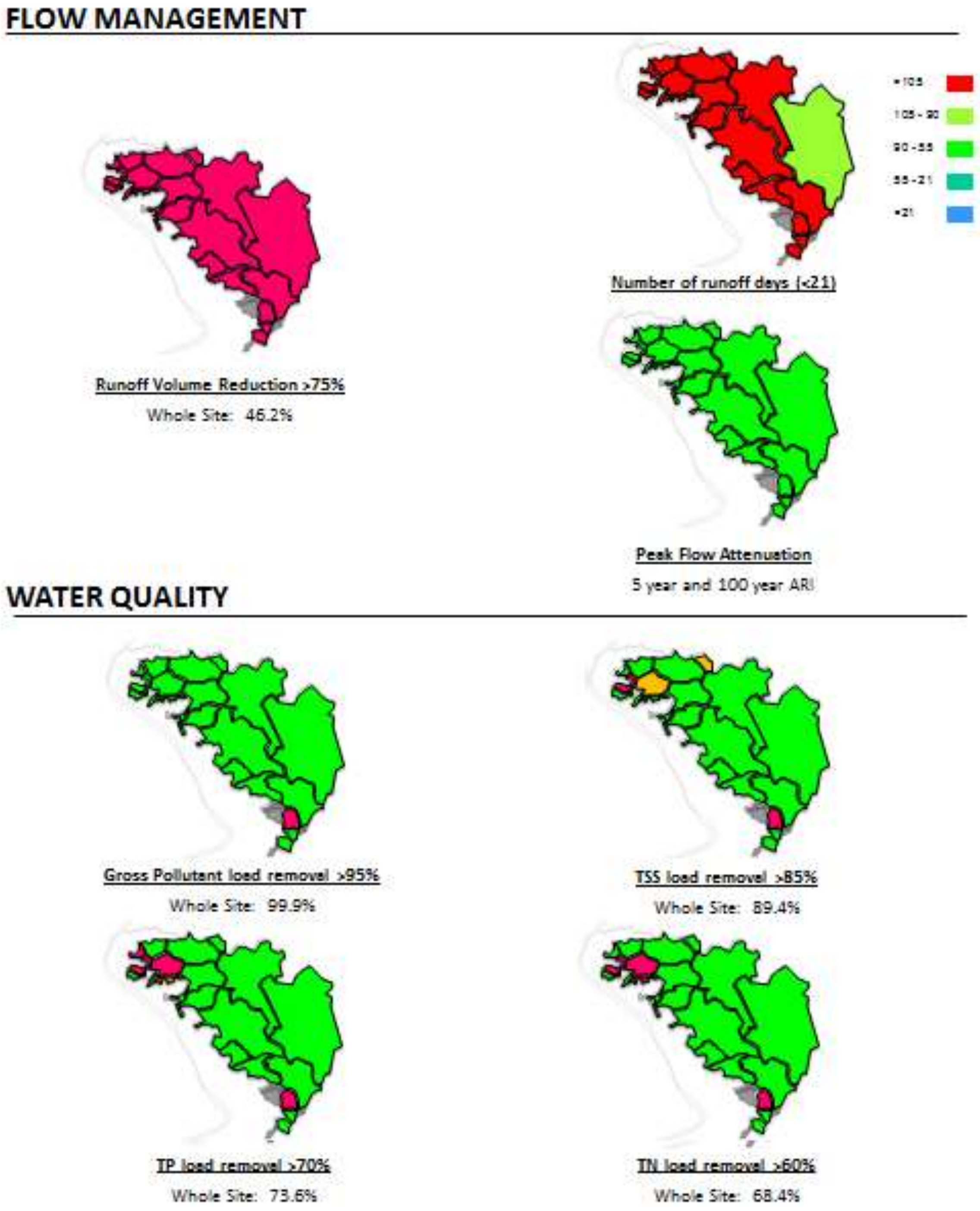


Figure 27 Environmental performance scorecard – 'intermediary case'

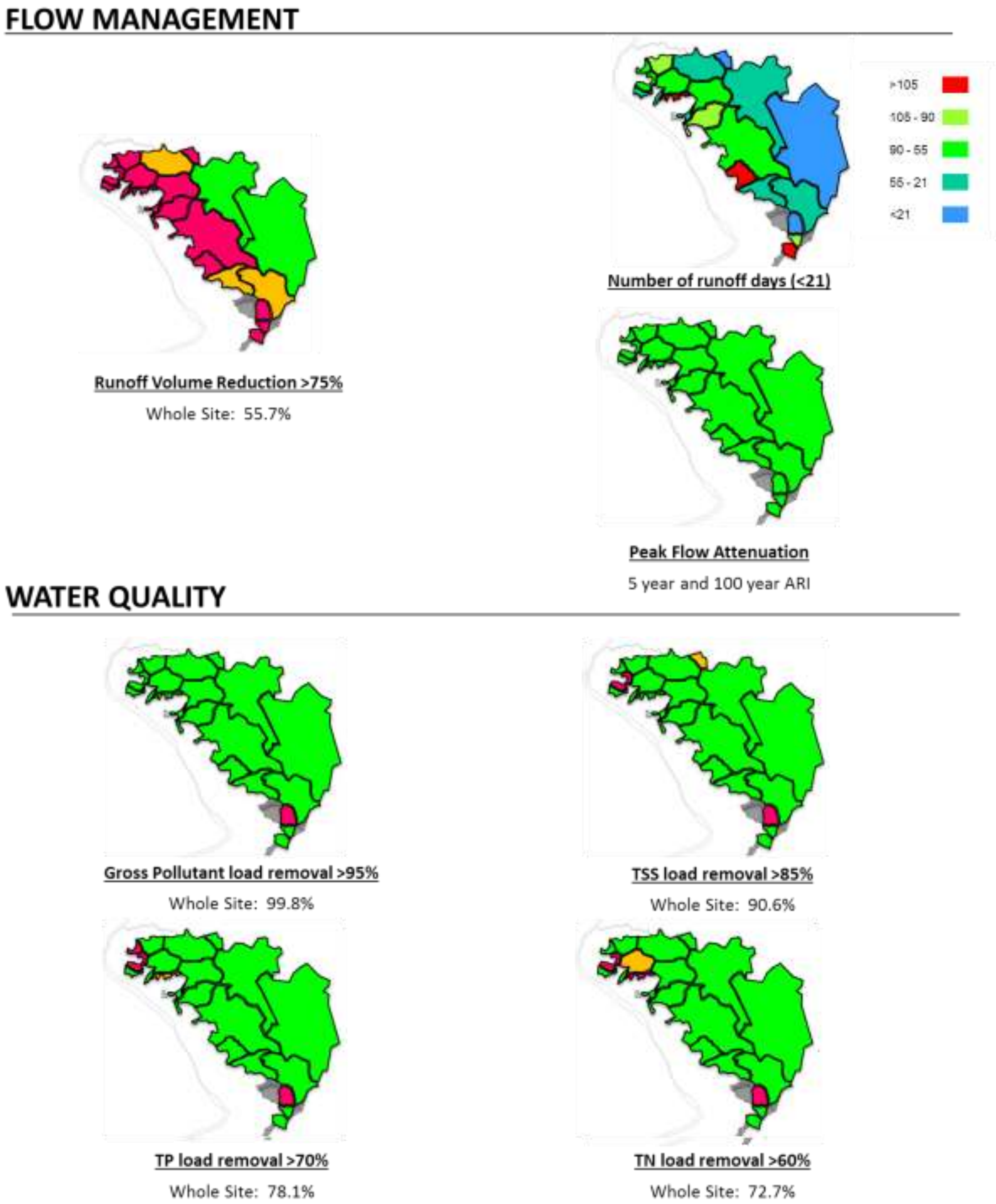


Figure 28 Environmental performance scorecards – 'aspirational case'

3.5.2 Green Star points self-assessment

The scenarios were evaluated against the *Green Star - Communities* criteria. Points would be awarded for stormwater runoff volume reduction, reduction in the frequency of runoff days (both made possible through extensive rainwater and stormwater harvesting), pollutant reduction (made possible by the stormwater wetland and ponds), and points would be awarded for the provision of alternative water supplies (from ponds and rainwater tanks, and wastewater), a potential total of 3.75 points (Table 20). The 'aspirational' scenario may also qualify for innovation points.

Table 20 **Points available for *Green Star - Communities*: self-assessment under each scenario**

Green Star Communities Criterion	Points Available	'Base case' scenario	'Intermediary' scenario	'Aspirational' scenario
ENV-8 Volume (75% reduction)	1	-	-	1
ENV-8 Frequency (5 to 1 days for 0.25 to 1 point) (15 to 5 days greater than natural runoff) (round up)	1	-	-	0.75
ENV-8 Pollutant reduction - 95% treated	1	1	1	1
ENV-7 Provision of alternative water sources to meet all non-potable water demand. All POS are on alternative water supply or not irrigated + proportion of GFA with access to alternative water sources to meet all non-potable demands	1	0.5	0.75	1
***ENV-7** Site wide leak detection (not addressed by this strategy)*	*1*	*n/a*	n/a	*n/a*
Total	**5**	**1.5**	**1.75**	**3.75**

3.5.3 Preliminary opinion of major infrastructure cost

The preliminary opinion of cost for all scenarios was supervised and verified by a Davis Langdon (an AECOM company) quantity surveyor.

The major infrastructure cost estimates presented below are in regard to the WSUD assets only. To determine the complete integrated water management system costs these needs to be considered in conjunction with additional cost elements that are being determined presently by Brown as the civil infrastructure design lead at West Belconnen (corresponding to stormwater conveyance and civil structures) in order to establish the total cost of stormwater and WSUD infrastructure on this project.

For reference, Table 21 below provides the breakdown of the various cost components.

Table 21 **Responsibilities for determining WSUD and stormwater infrastructure opinions of cost for the master planning studies**

Project cost Item	WSUD - AECOM	Stormwater & civil - Brown
Minor drainage network	○	●
Major drainage network (floodway's)	○	●
WSUD in streets (rain gardens)	n/a	n/a
Detention basins (integrated in WSUD measures)	●	○
Earthworks for WSUD measures including excavation and dam wall	●	○
Provision of lining of measures	●	○
Landscaping	●	○
Inlet and outlet structures	○	●
Dam wall armouring and spillways	○	●
Stormwater harvesting scheme	●	○

Project cost Item	WSUD - AECOM	Stormwater & civil - Brown
Non potable network	●	○
Potable network	○	●
Sewer network	○	●
Scour protection in Murrumbidgee River corridor	○	●
Pipe infrastructure in the Murrumbidgee River corridor	○	●

The opinion of cost is provided in Table 22 below.

Table 22 Infrastructure delivery cost comparison between ‘base’ and ‘aspirational’ water management scenarios

Infrastructure component	‘Base’	’Intermediary’	‘Aspirational’
Basins, wetlands and ponds[2]	$9.7M	$9.7M	$9.7M
Stormwater harvesting rising mains and pumps:	-	$6.8M	$8.6M
Stormwater harvesting tanks	-	-	$8.0M
Stormwater treatment plant	-	-	$17.0M
Non potable reticulation network (third pipe network)[3]	-	-	$48.4M
Total Infrastructure[1]	**$9.7M**	**$16.5M**	**$91.6M**
Preliminaries (15%)	**$1.5M**	**$2.5M**	**$13.7M**
Contingencies (30%)	**$3.4M**	**$5.7M**	**$31.6M**
Total Preliminary Estimate:	**$14.6M**	**$24.7M**	**$137M**

Table notes: 1. Excludes hydraulic structures: inlet/outlet/dam reinforcement and spillways and river corridor protection requirements that differ among the scenarios – these are being designed and costed by others. In comparing the scenario cost estimates, it is important to acknowledge that each scenario may have different major stormwater trunk and transfer requirements that may alter the relative costs of the overall water management strategies; 2. Assumes use of site material only – if clay lining requires imported material, an additional $8.5m may be required; 3. Cost estimate is based on that of the potable water network estimates developed by others working on the civil engineering master plan for West Belconnen

3.5.4 Discussion

All scenarios achieve very similar performances in areas of:

- Water quality improvement
- Peak flow attenuation.

There are however a number of key parameters for which the ‘aspirational’ scenario performance is vastly different, essentially relating to flow management:

- Stormwater volume reduction
- Runoff days
- Potable water substitution.

These are elaborated on below:

Water quality improvement

The ACT WSUD Code regional targets are amongst the most advanced in Australia today. The limiting factor for water quality improvement is the necessary reduction in annual load of Total Nitrogen. In order to achieve at least 65% removal, the associated water quality improvement for the other key pollutants is exceptionally good for a project of this scale: gross pollutants are nearly 100% removed, total suspended solids are being removed at about 90% and total phosphorus is reduced by 72%-78%.

Peak flow attenuation

The current *ACT Design Standards for Urban Infrastructure* require that stormwater peak flows be attenuated for design event including the 5 year ARI and 100 year ARI. With the necessary spatial and volumetric provisions provided in the various ponds and wetlands of the site, it is reasonably straightforward to achieve the necessary peak reduction for 2 year ARI events as well.

Sewage discharge

The nearby Lower Molonglo Water Quality Control Centre (LMWQCC) was identified early in the study as a potential supplier of treated wastewater effluent for non-potable water uses (as there are already similar schemes in place). However, a stormwater harvesting scheme has been preferred as an alternate source in the ‘aspirational’ master plan scenario based upon:

- Determining (through modelling) early that the surplus stormwater runoff being generated at the site would require novel management and disposal solutions, and there was an opportunity associated with this for beneficial reuse
- Identifying that it is likely that either stormwater or LMWQCC effluent reuse would require similar additional infrastructure to distribute the water and to treat it to meet the health risk management requirements of the *Australian Water Recycling Guidelines*
- If the LMWQCC effluent were used, the stormwater management infrastructure would need to include additional high-flow pipelines running down the river corridor and/or other scour protection measures in any case
- The LMWQCC effluent currently contributes to controlled environmental flows in the Murrumbidgee River for downstream irrigators. Using it on the development site would have other water balance accounting implications for the ACT under the Sustainable Diversion Limits set out in the Murray-Darling Basin Plan.

Stormwater volume reduction, runoff days and potable water substitution

The main point of different between the three scenarios comes from the benefits of undertaking the stormwater harvesting at a large scale under the ‘aspirational’ scenario. There are multiple layers of benefits from investing in the stormwater harvesting scheme including:

- A 38% improvement in stormwater volume reduction as compared to the ‘base’
- A vast improvement in the reduction of runoff days, with quite a number of sub-catchments in compliance with the current Australian best practice
- A 33% improvement in net potable water substitution.

Implications of different flow management performances

Overall, this project contributes to confirming that the ACT WSUD Regional targets for water quality are possibly the most advanced and represent best practice for Australia for the key constituents considered (TSS, TN, TP). However, the significant differences in the ‘aspirational’ as compared to the other scenarios also demonstrate the lack of flow management related objectives in the present ACT regulatory framework.

In the case of West Belconnen, better managing stormwater flows from a peak flow, and hydrological regime perspectives is more important than for a lot of comparable developments in the ACT. This is because of the high environmental value of the adjacent Murrumbidgee River corridor and the commitment from the Riverview and the Land Development Agency to protect the integrity and to support the rehabilitation of its habitat values of this land which includes a large number of drainage line and ephemeral streams.

While there is no doubt that the ‘base case’ delivers significant benefits, it is insufficient in itself to provide the necessary reduction in flows that may protect the Murrumbidgee River corridor. In short, though the costs of delivering the WSUD infrastructure are much greater under the ‘aspirational’ scenario, it would likely manage flow regimes in a way to limit any need for additional scour or piping protection in the corridor (see a detailed discussion at Section 8.0). Adopting the ‘base’ or ‘intermediary’ case options will require interventions and new flow discharge infrastructure works within the corridor itself. Currently the transfer infrastructure is being documented and costed by Brown the outcomes from this work may result in closing the gaps in the delivery cost estimates between the scenarios.

PART TWO

Evolution of the Master Plan

4.0 Site Analysis

4.1 Location

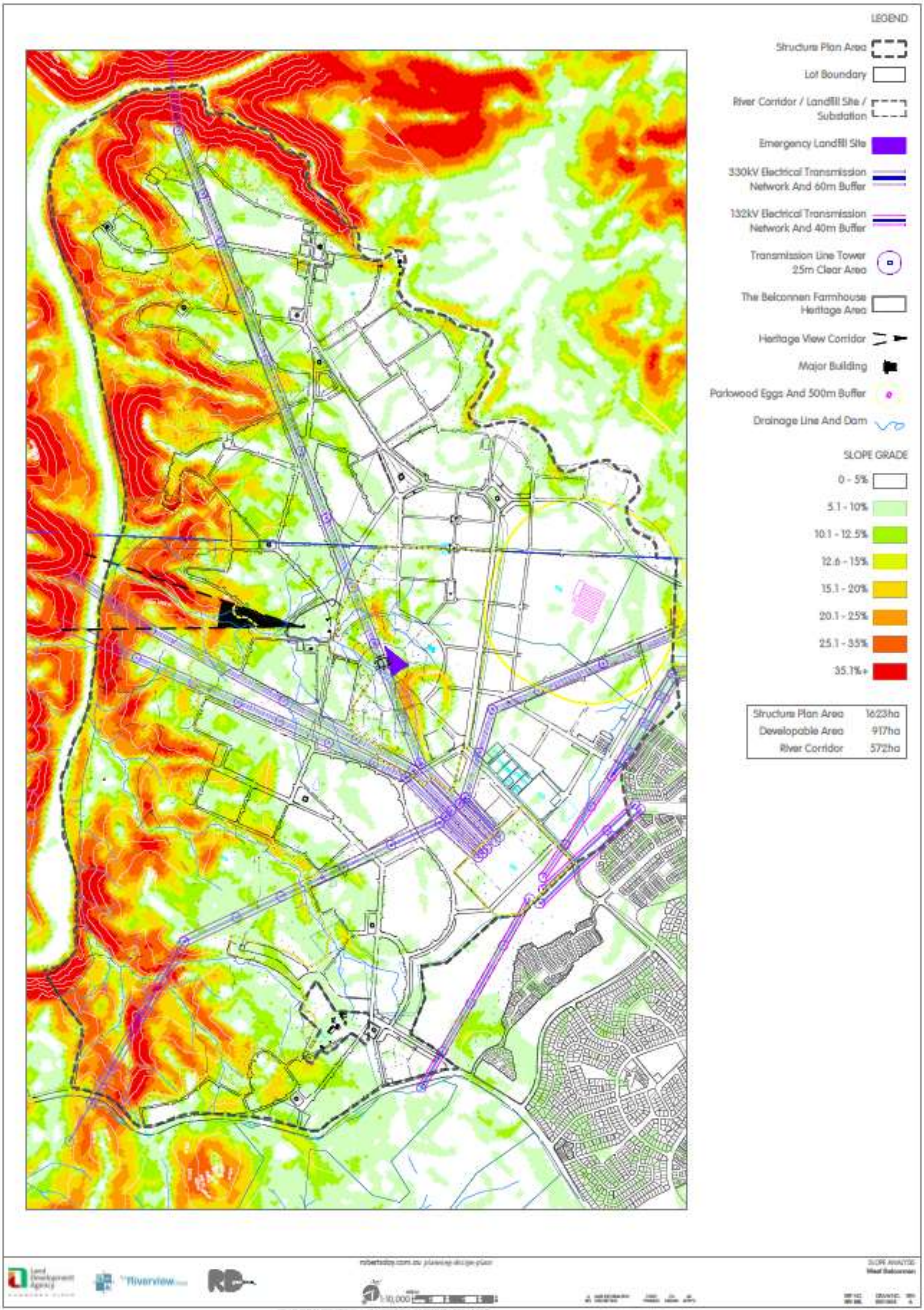
The West Belconnen site is located across the ACT and NSW state and territory border. It is bound by the Murrumbidgee River, Ginninderra Creek, Stockdill Drive and the adjacent suburbs of Holt, Macgregor and Dunlop and. The confines of the site are depicted in Figure 3. The total area of the site is approximately 1,450 hectares.

4.2 Topography

The greater extent of the site is comprised of a plateau with a rolling topography of shallow ridges and open valleys. The proposed urban development will be situated in this region of the site to facilitate construction. Along the western and northern perimeter, the site slopes steeply toward the Murrumbidgee River and more gently to the Ginninderra Creek. The land adjacent to these water courses is proposed to be designated as river corridor and no development is proposed in these areas.

Within the urban development area, the grades of the slopes range from 0% to 10%. However, adjacent to the river and creek, the grades become very steep and increase above 35% in places. The rolling topography is a particularly important parameter in the design of the community master plan and stormwater management in particular.

Figure 29 Site topography (courtesy Roberts Day)

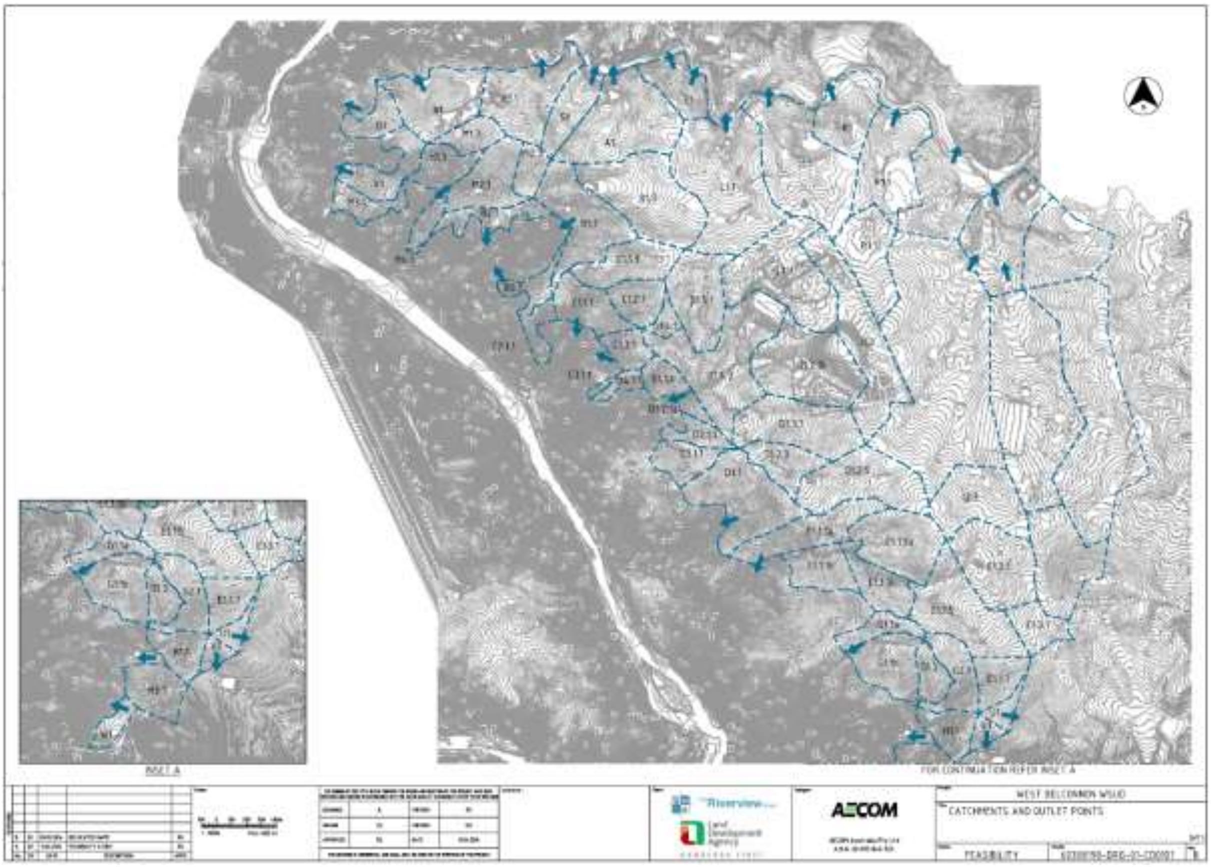


4.3 Catchments

The topography of the site and its grading towards both the north to Ginninderra Creek and the South to the Murrumbidgee River creates a large number of catchments on site.

4.3.1 Local catchments

Figure 30 **Local catchments**



There are 26 major drainage lines and discharge points in the receiving water ways for the site (Figure 30, note for a high resolution figure refer to the relevant drawing from the WSUD drawing set that accompanies this report). Associated with these are approximately 50 sub-catchments that were derived for this study to support the analysis and modelling of the site as well as the design of water management strategies.

4.3.2 Regional catchments

While the site proposed for development is of large proportions, it is located at the confluence of two major waterways with large regional catchments.

Ginninderra Creek catchment

Ginninderra Creek travels from Gungahlin within the Mulligans Flat Nature Reserve to the Murrumbidgee River where it ends at Ginninderra Falls. The Creek catchment is responsible for transporting about one quarter of Canberra's urban runoff and takes in approximately 32,000 ha of land[17]. The area includes Gungahlin and Belconnen within the ACT and also a portion of NSW. From Ginninderra Creek's confluence, the Murrumbidgee River in turn feeds the Murray River.

When the Canberra region began to be developed from a pastoral to an urbanised area the Ginninderra Creek catchment was dramatically modified: fauna and flora species were introduced and natural water flows were altered. Historically, early Europeans described the area with meadows surrounding rivers which would be ideal for grazing. Subsequently, the region was colonised and development began.

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[17] Ginninderra Catchment Group: http://www.ginninderralandcare.org.au/ginninderra-catchment-brief , accessed July 2014

Presently, the land uses within the Ginninderra Creek catchment include urban, rural residential, nature reserve and areas zoned for future development. Generally, land use above an altitude of 600 m tends to be nature reserve or broad acre rural; between 500 m and 600 m altitude urban and rural residential; and below 500 m altitude and at the Ginninderra Creek Gorge the land use tends to be broad acre farming and private nature park.

The West Belconnen portion of the Ginninderra Creek catchment (approximately 800 ha) represents about 2.5% of the total Ginninderra Creek catchment area.

Murrumbidgee River catchment

The Murrumbidgee River flows over 1,500 km beginning in the Snowy Mountains. Its flow is partially inhibited by the Tatangara Dam which provides water into Lake Eucumbene. From the Snowy Mountains it travels into the ACT for 66 km and then to western NSW, past Balranald, where it has its confluence with the Murray River.

The Murrumbidgee River catchment captures all of the ACT's stormwater. It is one of the major catchments contributing to the Murray-Darling river system and has many sub-catchments including the Ginninderra Creek catchment.

The total area of the Murrumbidgee River catchment is over 6,970,000 ha which include vast areas in eastern NSW downstream of the ACT. The Murrumbidgee River catchment located upstream of the West Belconnen site is approximately 1,141,000 ha[18]. The majority of the catchment area is made up of native grasslands and highly modified pastures. However in the snowy mountains region and adjacent to Canberra the catchment is predominantly made up native forests and woodlands.

The West Belconnen portion of the Murrumbidgee River catchment represents about 0.14% of its total catchment area.

4.4 Rainfall

Rainfall information is particularly important for projects where rainwater harvesting and stormwater harvesting are considered. For most stormwater related infrastructure including flood, drainage and network sizing, the design is based on statistically generated and significant 'design events'. These design events correspond to the expectation of rainfall precipitation for a range of frequency of occurrence. That is what is designated by Average Recurrence Intervals (ARIs). These values are calculated and documented by the Institution of Engineers Australia in the *Australian Rainfall and Runoff* documents and adopted by the ACT Government.

For rainwater and stormwater harvesting, a different set of data is required. In order to carry out water balance modelling that estimates (usually on a daily basis) the rainfall runoff processes, uses of water and water level in various storages, it is important that dependable, representative rainfall data is used.

At West Belconnen, an analysis of the available rainfall data sets was carried out. More information is provided below.

4.4.1 Rainfall data analysis

A number of rainfall stations were assessed to determine the most suitable for the West Belconnen site. The key purpose was to:

- Determine what is the most likely rainfall for the West Belconnen site (long term average, with some consideration of potential impacts of climate change on expected rainfall in Canberra)

- Find a rainfall intensity gauge (6 minute pluviograph station) in the nearby area that reflects the rainfall expected at the site to be used for to inform water quality modelling purposes.

The data was sourced from databases being maintained by the Bureau of Meteorology (BoM) and eWater[19].

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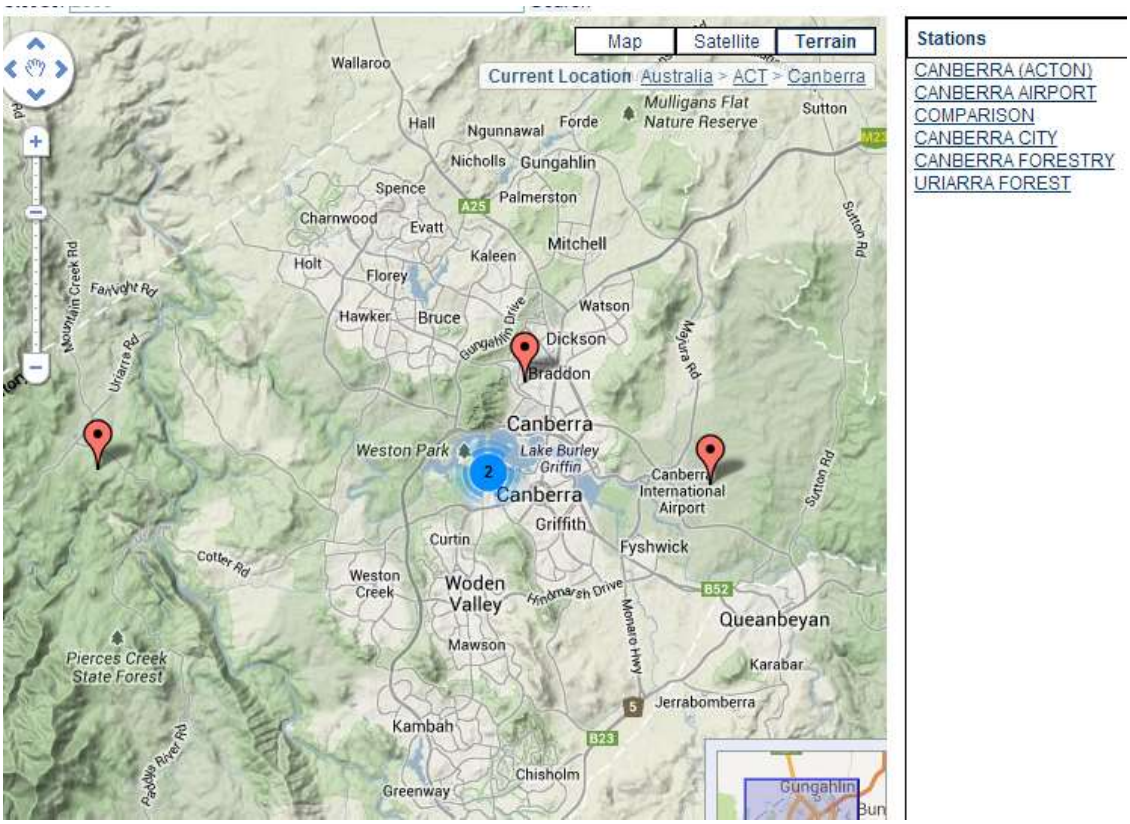
[18] Murrumbidgee Catchment Overview prepared by the NSW Office of Water at: file:///C:/Users/Julien/Downloads/catchment_overview_murrumbidgee.pdf, accessed July 2014

[19] See about eWater at: http://www.ewater.com.au/, accessed September 2014



CANBERRA (ACTON)
CANBERRA AIRPORT
COMPARISON
CANBERRA CITY
CANBERRA FORESTRY
URIARRA FOREST

Source: eWater[20]

Figure 31 Location of rainfall data stations

The time series information is presented in order of increasing average rainfall in Table 23 below.

Table 23 Rainfall data review

Average rainfall	Station	Time series	Years of data	Distance to West Belconnen	Notes / issues
534 mm/y	Canberra Airport Comparison (070014)	1996 – 2006	11	25 km	Time series suggested by *Green Star – Communities* as adequate representation
614 mm/y	Canberra Airport Comparison (070014)	1937 – 2010	72	25 km	Long term average
655 mm/y	Canberra Airport Comparison (070014)	1968 - 1977	10	25 km	Time series suggested by ACT WSUD Code as adequate representation
657 mm/y	Belconnen Weetangerra (070059)	1886 – 1987	100	7 km	Long term average Only daily (not 6min)
704 mm/y	Huntly (070093)	1956 – ongoing	60	5 km	Long term average Only daily (not 6min)
721 mm/y	Uriarra Forest (070085)	1965 - 1972	7	10 km	Pluvio data (6 min) Only short time series
798 – 812 mm/y 798 mm/y 806 mm/y 812 mm/y	Pierces Creek Forest (070070) Fairlight Station (070032) Uriarra Forest (070085)	1930 – 1990 1885 – ongoing 1927 - 2003	60 130 75	< 10 km	Long term average rainfall for other gauges near the site is high (800mm/y) Only daily (not 6min)

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[20] From: http://www.ewater.com.au/products/ewater-toolkit/urban-tools/music/pluviograph-rainfall-data-tool/ , accessed September 2014

The likely rainfall for the site appears to be significantly higher than for the Canberra Airport gauge that is used most commonly for analyses of local climate. The likely rainfall for the site may be in excess of 700 mm/year and potentially as high as 800 mm/y, in line with three long term average stations near the site. The nearest rainfall intensity gauge to the site (Uriarra Forest) only has 7 years' of data available, but has a long term average much closer to the expected average rainfall for the site.

4.4.2 Adopted rainfall data

The Canberra Airport (1968-1977) data set was selected for this project. This decision was driven by the following considerations:

- With an annual average rainfall of 655mm/y, the findings of the water balance modelling will be conservative
- This dataset is legislated in the ACT in the ACT WSUD Code and adopting this dataset will allow for consistency in the comparison with other infrastructure solutions in the ACT
- The time series suggested by the *Green Star - Communities* guidelines is highly unlikely to represent the conditions at the site (approximately 30% difference).

A sensitivity analysis including the consideration climate change effects (presented in Section 10.0) was used to understand the implications of the choice of dataset.

4.5 Existing hydrology

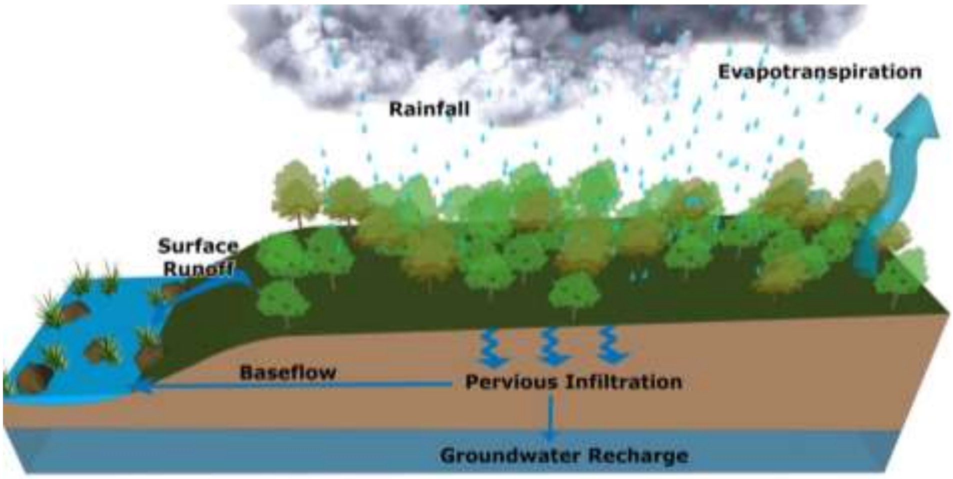


Figure 32 The natural water cycle

The proposed site's existing hydrology is resultant of the natural, pastoral environment. The majority of the area can be considered rural land, woodland or river corridor. Due to its natural environment the area can expect to have a higher rate of water absorption into the soil when compared to a typically urbanised area that has largely impervious surfaces. Therefore the natural environment has a high rate of water infiltration into the soil.

Typically, the impacts of urbanisation would decrease infiltration of water into the soil, increase runoff and reduce evaporation. Clever and innovative solutions must be utilised if a development wishes to lessen the impact on its existing hydrology.

4.6 Environmental values

Several environmental surveys and assessments have been undertaken at the site location. They highlight the significant environmental values of different flora and fauna that are evident in the area. The reports and their key findings are listed in Table 24.

There are many environmental factors that must be taken into consideration while planning the successful development of West Belconnen. The Pink-Tailed Worm Lizard is of national significance and the lizard's observed and potential habitats must be protected. Box gum woodland including areas of Yellow Box – Red Gum woodland is endangered within the ACT and retention and appropriate setbacks are required to protect it. Furthermore, as the area for development is largely pastoral land with homesteads and associated farming infrastructure, it may be possible that varying levels of contamination may be uncovered. This is also relevant to the landfill area that will require remediation.

It has already been determined that in recognition of the iconic natural features of the site, it is proposed to set aside about 550 ha which includes the Murrumbidgee River and Ginninderra Creek corridors to be maintained and managed for conservation, bushfire protection and recreation space.

Table 24 Environmental reports and their key findings

Author	Report Title	Key Environmental Findings
GHD	Report for West Belconnen Estate, Stage One Environmental Site Assessment (Amended)	- Land was previously agricultural and may include associated contaminants *e.g.* pesticides, fuels - Structures on site may contain asbestos - Two septic tanks exist with the potential for localised contamination - Recommend regular groundwater quality results - Recommend sampling be undertaken in areas of potential contamination
Kevin Mills & Associates	Flora and Fauna Assessment – Preliminary Assessment, Land at West Molonglo and Ginninderra Creek, New South Wales, Australian Capital Territory	- The southern part of the study area contains remnants of Yellow Box - Red Gum Woodland, endangered in the ACT - No threatened plant species identified - Endangered Pink-Tailed Worm Lizard identified in western area, close to river corridor - Superb Parrot may breed in south of study area - Speckled Warbler, not listed as endangered in the ACT however has a declining population; recorded in south of study area - Eastern Bentwing Bat not endangered but vulnerable - however no roost sites observed in areas to be developed
Kevin Mills & Associates	Further Flora and Fauna Studies, Land at West Molonglo and Ginninderra Creek	- Revised Murrumbidgee River corridor boundary was determined to follow relevant features - Along the Ginninderra Creek corridor almost all flora species are exotic excluding the River Oak - Species of flora and fauna along Ginninderra Creek are lacking in numbers, probably due to the highly modified character of the creek corridor
Will Osborne and David Wong, Institute for Applied Ecology, University of Canberra	The extent of habitat for the vulnerable Pink-Tailed Worm Lizard in the West Belconnen – Ginninderra Creek investigation area - confirmatory distribution surveys and mapping	Potential habitat for Pink-Tailed Worm Lizard mapped out and shows habitats along western study area near Murrumbidgee river corridor - Small confirmed areas near Ginninderra Creek however habitat not conducive to the lizard
K Nash & D McC Hogg	West Belconnen Woodland Areas Confirmatory Ecological Assessment	There is approximately 54 ha of box-gum woodland within the strategic assessment area of West Molonglo - this includes areas of Yellow Box-Red Gum grassy woodland which is considered to have high conservation value
Kevin Mills & Associates	Flora and Fauna Surveys and Assessments West Belconnen Project Area, The Riverview	- No evidence of Superb Parrot breeding areas in study area - No threatened species were observed in tree hollows
Kevin Mills & Associates	Flora and Fauna Studies, Draft, Land of Parkwood Road and Ginninderra Creek. Yass Valley Council, New South Wales	Important conservation issues: - Murrumbidgee River and Ginninderra Creek watercourses and adjacent riparian vegetation and habitats - The woodland provides animal habitat - Area identified as habitat for pink tailed worm lizard is of national importance as large population found here - Superb parrot, golden sun moth and woodland birds do not appear to be impacted by proposed development - Only a handful of trees with hollows occur and are of

Author	Report Title	Key Environmental Findings
		minimal value due to their isolation and small number Development should take into account the following: - Designation of habitat along Ginninderra Creek - Retention and appropriate setbacks to Pink-Tailed Worm Lizard habitats - Retention and appropriate setbacks to woodland areas - consideration of water quality in the river and creek - revegetation along Ginninderra Creek with the local vegetation through a management plan

4.7 Existing land-uses

The site is currently being rezoned to permit future development.

The site location has a variety of land uses including the West Belconnen Resource Management Centre, the Canberra Substation, a quarry and agricultural/pastoral land. The Canberra Substation, along with the recently completed Williamsdale Substation, supplies Canberra with its electricity needs. Energy is transported into the substation on Parkwood Road via several major power line routes. This substation is critical to Canberra’s infrastructure.

The quarry on Parkwood Road mines Ginninderra Red Granite which is decomposed granite that is commonly used around Canberra as decorative landscaping gravel (owner: Tharwa Sands). The quarry is within NSW and is owned by a local farmer. The homesteads and paddocks of this area are also owned by farming families.

Other businesses that operate within the site vicinity include Parkwood Eggs, The Garden Plant Nursery, Angels of Mercy Veterinary Hospital and Best Friend Pet Centre.

4.8 Critical infrastructure

The site is predominantly agricultural and pastoral, with some economic activities as outlined in section 4.7. The extent of existing infrastructure on site is limited to:

- A network of local roads
- Fences and associated agricultural assets
- A large number of small farm dams
- A few large farm dams
- Electrical infrastructure including a major substation for Canberra’s power supply, major power line easements and a large number of electrical pylons and towers.

The power infrastructure asset is considered absolutely critical on this project and cannot be impacted or altered. There are a number of reasons for this including:

- High costs associated with any relocation
- Technical difficulties and design challenges associated with any modification of the network
- Strategic value of the assets to the ACT and region
- High potential for disturbance to the local economy

The water management and WSUD infrastructure design needs to integrate the power infrastructure constraints

4.9 Working with constraints – a summary

Delivering on the various water cycle management strategies, a number of elements of infrastructure are required. These are outlined in Section 3.0. There is a relatively high level of flexibility with many WSUD infrastructure components including the network of raising mains and reticulation system for stormwater harvesting, the pump stations and the proposed storage tanks. The careful integration of constraints is however required for the various ponds and wetlands and the proposed stormwater treatment plant.

The key constraints that were considered during the stormwater and WSUD design process are summarised below:

Table 25 Summary of key design constraints for the stormwater infrastructure

Key constraint	Method of integration
Topography	
High number of sub-catchments and discharge points	Develop a stormwater treatment for each sub-catchment that meets the adopted water quality and flow management objectives.
Steep terrain	Optimise the location of ponds, wetlands and basins to minimise the earthworks associated with excavation and dam wall construction. Optimise the location of ponds and wetlands to enable consolidation of catchments using cut-off drains and minor site regrading. Maximise the use of existing farm dams.
Defined valleys and drainage corridors	Work with the topography and influence urban design and planning to work with contours. Identify major valleys and drainage lines to be included as part of the Green Infrastructure network including stormwater, flood corridors, WSUD and public open space assets.
Murrumbidgee River corridor	
Protected area	Stormwater measures cannot impact the Murrumbidgee River corridor integrity, whether by their location, earthworks or construction phase unless previously discussed and agreed by the environmental consultants
Sensitive ephemeral drainage gullies	Gullies need to be protected from the potential erosion and scour impact associated with urban stormwater excess. All efforts to be made to ensure that gullies do not form barriers to the connectivity of the Murrumbidgee Corridor habitats
High natural and visual amenity	Minimise the visual impact of dam embankments by limiting embankment heights and appropriate selection of location. Minimise the need for any civil engineering structure within the Murrumbidgee River corridor. Adopt below ground structures instead of above ground whenever possible.
Pink-Tailed Worm Lizard habitat and other high environmental value assets	No impact on the Pink-Tailed Worm Lizard habitat within the Murrumbidgee River corridor including a 20m buffer. No impact on listed Yellow Box woodland habitats in the urban development area. No impact on ‘exceptional’ classified trees. Limit impact on ‘high value’ classified trees.
Power Infrastructure	
Easements	Stormwater measures can be located in the easements providing that there is no impact on towers and access can be maintained around the measures for future maintenance
Towers	No impact on power towers and their associated clearance zones

5.0 Developing the integrated water management scenarios

5.1 Overview

The proposed master plan and integrated water management strategy outlined in Section 3.0 represents the final evolution of an iterative approach to determine a strategy that would heighten the water and environmental outcomes (against the key drivers and preliminary evaluation criteria listed at Section 3.1 and 3.2) for the future community at West Belconnen.

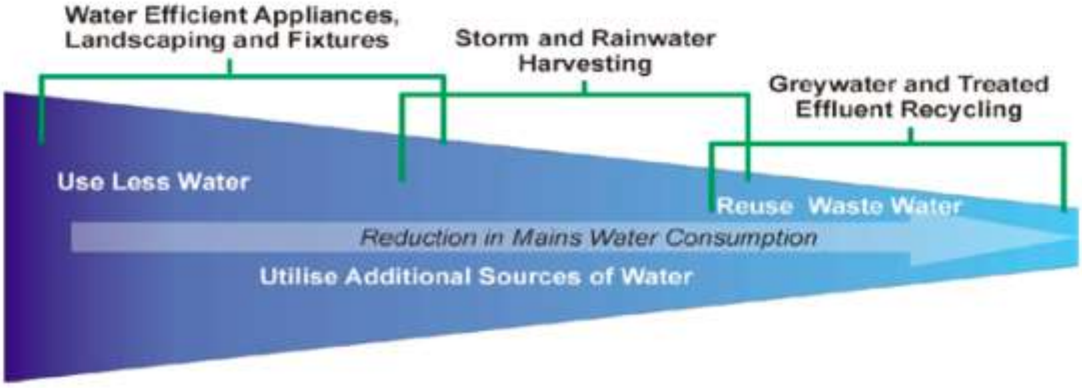
Deriving this strategy and influencing the structure plan for the West Belconnen project took several steps which are outlined in this chapter.

The key steps included:

- Early development of proposition for the ‘base case’ and ‘aspirational’ water management scenarios by establishing a rationale and framework for prioritising the various water sources on the project
- Estimating current and future water demands for various uses
- Testing a range of scenarios for water quality and flow outcomes using a representative trial model
- Collaboration with other specialists and stakeholders to test, refine and validate the strategies.

5.2 Water cycle management priorities

The ACT WSUD Code sets a preferred order of implementation measures to reduce reliance on mains water (Figure 33). To that end the focus of the early stages of the study were to determine water demands commensurate with water efficient buildings and landscapes, and match storm and rainwater harvesting opportunities to the nature of the community needs as they evolved and were captured in the overall community structure plan (which was happening concurrently to this work, led by the firm Roberts Day).



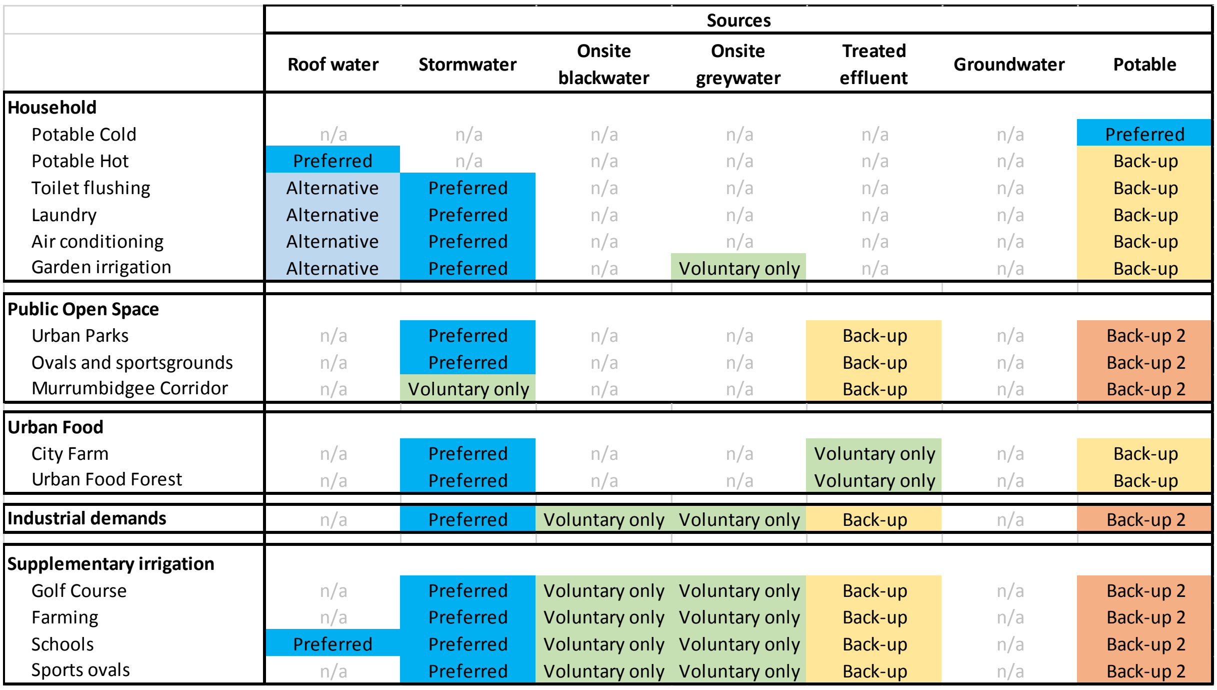
Credit: ACT WSUD Code (ACTPLA, 2009)

Figure 33 Implementation priorities for reducing reliance on potable water

With the ambitious targets for flow management and urban stormwater excess reduction by 75%, it was critical on the West Belconnen project to establish early the priorities for the water cycle management and the best allocation of demands to the various potential water sources. Figure 34 below summarises the priorities and most suitable combination of water demands to the range of potential water sources, and these are reflected in the layout of infrastructure and descriptions of the proposed ‘aspirational’ master plan set out in Section 3.0. These priorities started out through a consideration of practices elsewhere in Australia and the study team’s experiences on what constitutes appropriate alternate water resources for various uses. It evolved over time as the understanding of the study site, the community master planning and the site constraints became better understood.

The first priority for the water cycle management strategy is to capture, treat and reuse as much of the stormwater as possible. With the WSUD measures proposed, stormwater should be of relatively good quality for an urban community setting, and this can have advantages in ensuring the quality is adequate for the matched uses (subject to appropriate management). The urban stormwater excess is sufficient to supply most the demands on site with high reliability and still have excess water that could be exported away from the site for beneficial consumptive uses. It has the added benefit of mitigating peak flows into the nearby waterways, a key water management requirement.

Treated effluent is locally available from the Lower Molonglo Water Quality Control Centre (LMWQCC) and was considered early in the study as a potential alternate water source. However for various reasons it was considered a secondary priority as a resource for this site to the stormwater, as discussed further in Section 6.0.



	Sources						
	Roof water	Stormwater	Onsite blackwater	Onsite greywater	Treated effluent	Groundwater	Potable
Household							
Potable Cold	n/a	n/a	n/a	n/a	n/a	n/a	Preferred
Potable Hot	Preferred	n/a	n/a	n/a	n/a	n/a	Back-up
Toilet flushing	Alternative	Preferred	n/a	n/a	n/a	n/a	Back-up
Laundry	Alternative	Preferred	n/a	n/a	n/a	n/a	Back-up
Air conditioning	Alternative	Preferred	n/a	n/a	n/a	n/a	Back-up
Garden irrigation	Alternative	Preferred	n/a	Voluntary only	n/a	n/a	Back-up
Public Open Space							
Urban Parks	n/a	Preferred	n/a	n/a	Back-up	n/a	Back-up 2
Ovals and sportsgrounds	n/a	Preferred	n/a	n/a	Back-up	n/a	Back-up 2
Murrumbidgee Corridor	n/a	Voluntary only	n/a	n/a	Back-up	n/a	Back-up 2
Urban Food							
City Farm	n/a	Preferred	n/a	n/a	Voluntary only	n/a	Back-up
Urban Food Forest	n/a	Preferred	n/a	n/a	Voluntary only	n/a	Back-up
Industrial demands	n/a	Preferred	Voluntary only	Voluntary only	Back-up	n/a	Back-up 2
Supplementary irrigation							
Golf Course	n/a	Preferred	Voluntary only	Voluntary only	Back-up	n/a	Back-up 2
Farming	n/a	Preferred	Voluntary only	Voluntary only	Back-up	n/a	Back-up 2
Schools	Preferred	Preferred	Voluntary only	Voluntary only	Back-up	n/a	Back-up 2
Sports ovals	n/a	Preferred	Voluntary only	Voluntary only	Back-up	n/a	Back-up 2

Figure 34 Allocation of priorities for demands and sources

It is acknowledged that Aquifer Storage and Recovery (ASR), as a method for managing excess water and/or storage for beneficial uses has not been considered in any significant way as part of this study. Such schemes where feasible are typically a very cost effective proposition. Relying on the injection of harvested non-potable water (stormwater or treated effluent) into an underground aquifer, ASR scheme have the capacity to store large volume of water for relatively low upfront costs. The injection and later extraction of water using a system of pumps can be associated with reasonably high operation and maintenance costs. For the West Belconnen area, there has been no dedicated investigation in the past to try and ascertain the potential for groundwater systems to accommodate an ASR scheme.

5.3 Water demand projections

5.3.1 Household water use

In the ACT, the ACT Planning and Land Authority (ACTPLA) has carried out an analysis of ACTEW Water's water consumption data in order to establish the breakdown of end uses. This was reported in *Think Water, Act Water* (ACT Government, 2004) and the ACT WSUD Codes. The consumption data that was developed was recorded in 2003.

Historical water usage data for Canberra is tabulated below, and uses 2.6 as the average number of people per dwelling. The internal water usage is 465 L/day/household, *i.e.* 179 L/person/day.

Table 26 Average water consumption in a Canberra dwelling (historical – prior to 2003)

Area of water consumption	*%*	*L/day*	*Average L/person/day*
Bathroom	20%	163	63
Laundry	13%	106	41
Kitchen	6%	49	19

Area of water consumption	*%*	*L/day*	*Average L/person/day*
Toilet	18%	147	56
Garden	39%	318	122
Other outdoor	4%	33	13
TOTAL:	100%	815	313
Internal uses:	57%	465	179

Water use assumptions for the modelling for the West Belconnen site needed an additional breakdown of hot water demands (potentially connected to rainwater tanks) and needed to reflect the smaller lot sizes, probable occupancy ratios and improvements in water fixture efficiency that has occurred over the last 10 years.

The internal water demands adopted for West Belconnen were based on information available through a report by Yarra Valley Water (2013) which has been adopted in work for the growth corridors in Melbourne after extensive discussion by various stakeholders. There is some averaging of household sizes in the simplified table below and simplification of categories, and distribution of internal and external contingency allowances for ease of modelling at this strategic scale of work for West Belconnen.

For West Belconnen, the average number of people per dwelling is assumed as 2.6, and the values at Table 27 were adopted. The internal water usage is 337 L/day/household, 130 L/person/day (*i.e.* a 27% reduction on the historical internal usage in Canberra), implying some significant water usage savings through higher efficiency water devices and changed behaviours.

Table 27 Adopted household water demands (adapted from Yarra Valley Water, 2013)

Use	L/household/d	L/p/d
Potable demand (L/p/day)	105	40.5
Hot water	107	41.3
Toilet flushing	60	23
Laundry (cold)	65	25
Irrigation (private)	67	25.8
Total water usage	405	156
Internal water usage	337	130

5.3.2 Irrigation water requirements at West Belconnen

The *ACT Water Act 2007* Schedule 1 determines that the volume of water for irrigation of public open space parkland, sportsgrounds and residential gardens is considered to be 0.5 ML/1,000 m^2 *per annum.* For the near 100 ha of public open space (McGregor Coxall, 2014), this equates to an annual demand of 500 ML. To understand the irrigation requirements in an ACT context for other types of crops it was necessary to develop a suitable approach, which is outlined at Appendix h. The figures below summarise the outcomes of the analysis

It is evident that crops require more irrigation throughout the summer months (December, January and February) and require little or no irrigation throughout the winter months (June, July and August). Crops that require the greatest source of irrigation water include tomatoes, potatoes, peas, mint, apple/cherry/pear trees and stone fruit trees. Crops that require very little irrigation include cantaloupe, strawberries, citrus trees and olive trees. Cumulatively, vegetable crops will require an additional 586 mm of water *per annum* in irrigation and fruit trees would require an additional 559 mm *per annum*.

Figure 35 Irrigation water demand for vegetables and fruits in the ACT

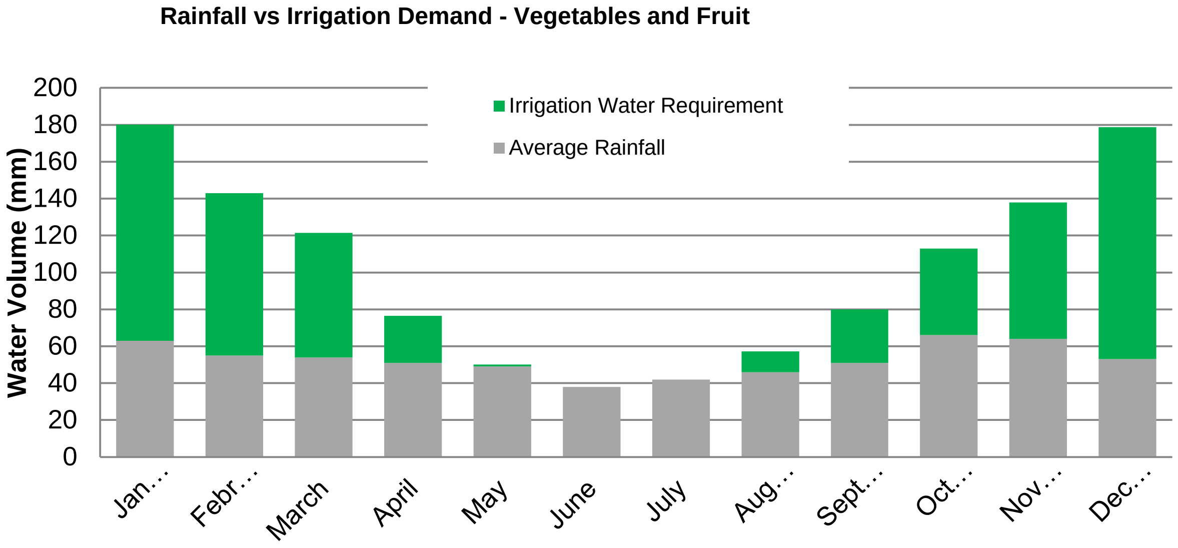
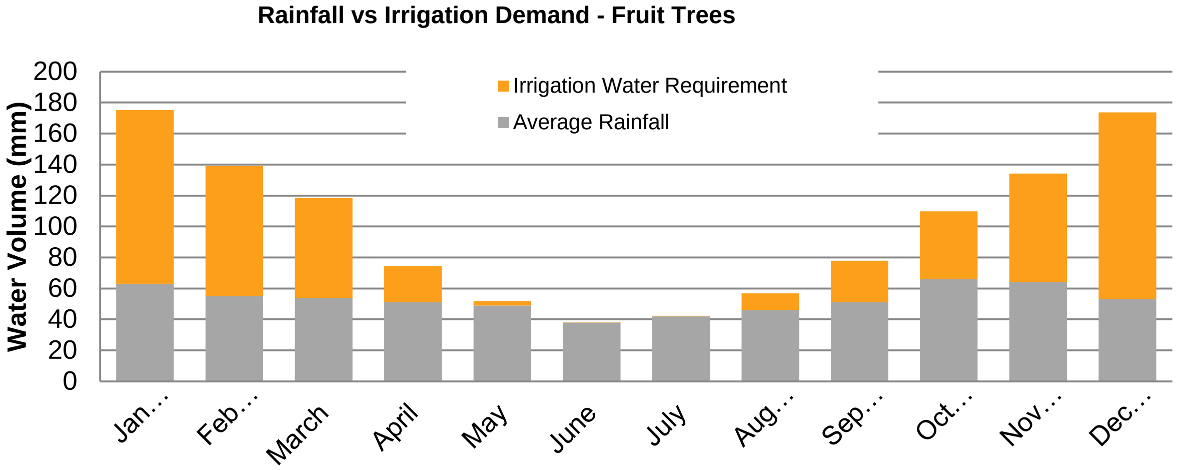


Figure 36 Irrigation water demand for fruit trees in the ACT



As such, the irrigation demand for the West Belconnen project was derived as outlined below.

Table 28 West Belconnen irrigation water demands in addition to public open space

Landuse	Area (ha)	Mean annual demand (ML/y)
Ovals	20	100.0
City Farm	9	55.4
Urban orchard	8	44.8
Total	37	200.2

In addition to the public open space irrigation, it is estimated that the future irrigation demand to sustain the local ovals, city farm and urban orchard would be in order of 200 ML *per annum* on average.

5.3.3 Potential irrigation demand off-site

With the volumes of urban stormwater excess generated, it may be possible to export harvested stormwater from the site to other offsite users and contribute to reducing the volume of stormwater that drains to drainage gullies of the Murrumbidgee River corridor.

A strategic review of opportunities for stormwater reuse was carried out in order to estimate the potential for water to be provided in the proximity of the site. The key sites identified and their potential demand is tabulated below.

Table 29 Potential current irrigation demands in proximity of the site

Site	Estimated grassed areas (ha)	Estimated Irrigation Area (ha)	Potential demand (ML/y)	Distance from West Belconnen (m)
Magpies Belconnen Golf Club	74.6	59.7	301.02	800
Kippax District Playing Field	20.4	16.3	82.09	2100
Kingsford Smith (Super School)	5.7	4.6	23.03	2450
Holt Neighbourhood Oval	6.4	5.15	25.95	2000
Higgins Neighbourhood Oval	8.8	7.1	35.62	2350
Total	**116.0**	**92.80**	**467.70**	**9700**

5.4 Trial arrangements for water balance and quality modelling

5.4.1 Why trial arrangements were needed

It was necessary for the integrated water management strategy for the project to be progressed alongside the development of the concurrent town planning, urban design and transport planning and infrastructure. This was an iterative process. In order to inform the early planning stages and guide the development of an integrated design outcome, the first phase of the project involve the trial of a large number of scenarios using a representative ‘theoretical catchment’ of 100 ha.

The objectives of the trial phase were to:

- Test and validate the most suitable water cycle management strategy
- Test and validate the most appropriate stormwater treatment train that would deliver on the water quality and flow management objectives
- Strategically test the level of performance from preliminary strategies
- Resolve the general orientations of water management for the project to identify preliminary footprints and provisions for WSUD assets including wetlands and ponds to inform town planning.

More information on the trial arrangement is provided below. It is important to note that while the information below was useful in progressing the design, they do not correspond to the latest refinement of the strategy that was presented in the Section 3.0.

5.4.2 Representative 100 ha ‘theoretical catchment’

In liaison with landscape architects, urban designer and town planners, the most appropriate representative catchment was discussed and agreed as follows:

Table 30 Theoretical 100 ha catchment breakdown for WSUD trials

Land use	Proportion	Imperviousness
Residential area	57.5%	70%
Road corridors	25%	90%
Public open space and drainage	17.5%	5%
Total	**100%**	**64%**

Note the following assumptions were made at this time:

- Rainwater tanks: connected to non-potable or hot water demands (2 kL tank for each lot, 92% reliability, average roof area connected to tank: 305m^2/lot)
- Wetlands used to manage stormwater quality:0.35m extended ponding, 0.35m wetland depth, infiltration 0.04mm/hr (organics deposited on heavy clay)
- Pond system facilitates harvesting and flow reduction : 0.1m extended ponding, up to 0.5m drawdown, infiltration 0.36 mm/hr (heavy clay)
- Reticulation network from pond to dwellings and public open space areas supplies harvested stormwater for toilet flushing, laundry (cold water) and irrigation in private gardens and in public open spaces
- Three climatic time series were compared for the modelling
  - rainfall record from Canberra's Airport (1968 -77, average annual rainfall of 655 mm/y)
  - rainfall record from Canberra's Airport (1996 -2006, average annual rainfall of 534 mm/y)
  - rainfall record from Uriarra Forest (1965 -72, average annual rainfall of 712 mm/y)
- A water disposal field is simulated in some scenarios to efficiently achieve the 75% flow reduction target described at Section 2.6.4. This would require flows to be transferred (most likely by pumping) to a suitable area for land disposal (potentially irrigating selected food production crops / landscaped areas).

The theoretical catchment was modelled using MUSIC v6 software to test the validity and key orientations of the strategy scenarios. Key results are provided below.

5.4.3 Key findings

The results of the MUSIC model assessment are described in Table 31

Table 31 Results of MUSIC modelling for first trial of a prototype water strategy

Treatment parameter	Results of assessment	
Rainwater tank	84% demand met (toilet, laundry, irrigation)	
Wetland/pond area	4 ha (3ha wetland + 1ha pond)	
Stormwater quality performance	Wetland	Pond (reuse)
	89% TSS reduction 77% TP reduction 57% TN reduction	91% TSS reduction 81% TP reduction 65% TN reduction
Third pipe network (non-potable supply)	None	
Irrigation of public open spaces with harvested stormwater	56% of demand met Requires network connecting to open spaces	
Flow management	Wetland	Pond (reuse)
	22 % flow reduction	40 % flow reduction
Flow days (comparison with 6 days of surface runoff for the predevelopment simulation of a fully pervious site)	128 days surface runoff from the development	

This scenario assumed irrigation of public open spaces (10 ha) using harvested stormwater. If potable water or recycled wastewater was used to meet this demand the stormwater quality targets are not met and the flow reduction is reduced to 22%.

The results of the MUSIC model assessment for the preferred scenario are described in Table 32

Table 32 Results of MUSIC modelling for first trial of 'aspirational' water strategy

Treatment parameter	Results of assessment
Rainwater tank	92% demand met (hot water)
Wetland area (3 ha) and pond area (1 ha) = Total 4 ha	4 ha

Treatment parameter	Results of assessment
Stormwater quality targets met	97% TSS reduction 91% TP reduction 85% TN reduction
Third pipe network (non-potable supply)	Yes
Stormwater Reuse: (toilet flushing, laundry, irrigation of private gardens and public open spaces)	70% of demand met 93 ML of water reused
Field for water disposal	7 ha
Flow management	75 % flow reduction
Flow days (predevelopment = 6 days)	23 days

The preferred strategy uses the same treatment footprint (4% of catchment area) but exceeds the water pollution reduction targets, and meets the requirements for flow reduction. This is achieved through the centralised stormwater harvesting initiative.

Beyond the demands identified for non-potable water on site including at the household level and for public open space irrigation, additional disposal of stormwater is required in order to achieve the 75% reduction in stormwater flow volume target. This could be done using an irrigation scheme either for simple disposal (evaporation/infiltration field) or for consumptive uses (off site irrigation of golf courses or sports facilities).

The modelling results indicated that the additional disposal of stormwater requires about 7% of the land to meet the 75% reduction target. That represented approximately 85 ha for the entire West Belconnen development.

5.5 Planning and design forum

The study team participated in the West Belconnen ‘Planning and Design Forum’ which was held from November 11-14, 2013. The forum was an opportunity to gather the entire team of consultants working on the master plan, key stakeholders, the neighbouring community in Belconnen and the general public to share ideas, discuss opportunities and potential approaches to developing the site.

The WSUD strategy team were in particular involved in the following sessions:

- Session on Water, Sewerage and Electricity (organised by civil engineering consultant, Brown)
- Session on Public Open Space Framework (organised by landscape architect, McGregor Coxall)
- Session on Waste Water Recycling (Integrated Water Management) (organised by WSUD consultant, AECOM)
- Session on Opportunities + Constraints + Big Ideas (organised by landscape architect, McGregor Coxall)
- Session on West Belconnen “A 21st Century Garden Suburb” (organised by structure plan lead, Roberts Day)

A detailed report for the Planning and Design Forum sessions is available from the West Belconnen project website (available at: http://talkwestbelconnen.com.au/planning/planning-process/ [last accessed July 2014]).

The key water management outcomes from the forum as captured in session were:

- The general support for the objectives and principles of the Integrated Water Cycle Management for the project (those set out in Section 2.0)
- The strong support for protecting the water quality and integrity of the local waterways, Ginninderra Creek and its falls as well as the Murrumbidgee River
- Concerns around adequately addressing public health related issues for the range of alternate water resource initiatives proposed as well as ongoing operation and maintenance costs at the household level as well as for the public open space and WSUD assets.

For the details of water related comments and issues, please refer to the *Planning and Design Forum Report* (Elton Consulting, 2013:32-35).

6.0 Opportunities for alternate water sources

6.1 “Fit for purpose” and ACT WSUD Code

The ACT WSUD Code (ACTPLA, 2009:17) states that new developments “will need to bear a higher proportion of water use reduction”. Implementation of WSUD in new developments supports the reduction of water use by helping to make developments less reliant on external water sources.

To maximise efficiency a “fit for purpose” approach should be taken when considering reuse initiatives for available water. “Sustainable water resource management, benefits the life and operation of water supply infrastructure and allows better provisions to be made for environmental flows” (Engineers Australia, 2006:1-3).

The ACT WSUD Code demonstrates the opportunities for water reuse in a fit for purpose application in the following table.

Table 33 Opportunity for matching alternate water sources and uses (adapted from ACTPLA, 2007)

Source	Irrigation	Kitchen		Laundry		Toilet	Bathroom	
		Cold	**Hot**	**Cold**	**Hot**		**Cold**	**Hot**
Mains Water	3	1	2	1	2	3	1	2
Wastewater								
Treated effluent	2	4	4	4	4	2	4	4
Grey water	1	4	4	4	4	1	4	4
Stormwater								
Roof water	2	2	1	1	1	2	2	1
Non-roof water	2	4	4	4	4	2	4	4

1 = Preferred Use **2 = Compatible Use** **3 = Non-preferred Use** **4 = Not Compatible**

6.2 Current practice

Generally, rainwater tanks are common while grey water reuse is occasionally employed in the ACT for toilet flushing and irrigation on a voluntary basis. Today there is no large scale wastewater recycling scheme in the ACT and region. While the number of urban development projects including non-potable water supply is expanding in other Australian states, there is to date only one small pilot scheme operating in Canberra: the North Canberra Effluent Reuse Scheme.

In the North Canberra Effluent Reuse Scheme, wastewater is treated at the Fyshwick Sewerage Treatment Plant and pumped into the Lower Russell Reservoir. As part of the scheme, the reservoir supplies irrigation water to seven sites for irrigation totalling 70 ha across North Canberra[21].

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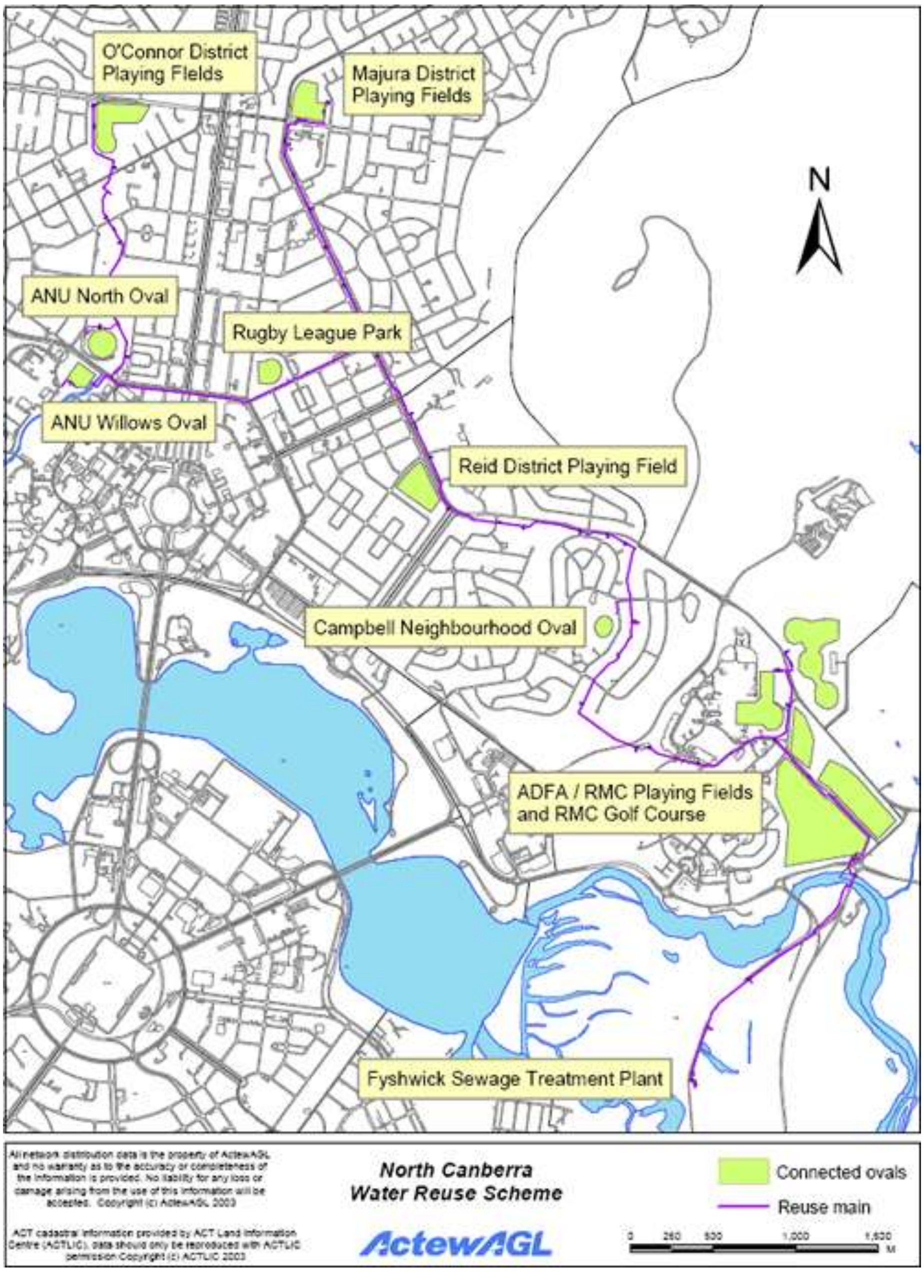
[21] ACTEW Water at: www.actew.com.au, accessed September 2014



Credit: ACTEW Water[22]

Figure 37 North Canberra Water Reuse Scheme diagram (ACTEWAGL, 2011. Available from http://www.actew.com.au/Water%20and%20Sewerage%20Systems/ACT%20Sewerage%20System/Recycled%20Water/North%20Canberra%20Effluent%20Reuse%20Pipework.aspx)

The treatment process undertaken in the scheme has the following steps:

- Pre-treatment
- Membrane filtration
- Post-treatment

During pre-treatment, raw effluent is dosed with chemicals and then runs through a pre-filter screening system. The membrane filtration utilises cassette type filters that can be added or removed depending on the flow capacity required. Currently the system is running at approximately 50% at 20 L/s but the plant has capacity to process 40 L/s of effluent. The filtered water is then disinfected with chlorine gas during the post-treatment step.

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[22] Available from: http://www.actew.com.au/Water%20and%20Sewerage%20Systems/ACT%20Sewerage%20System/Recycled%20Water/North%20Canberra%20Effluent%20Reuse%20Pipework.aspx, accessed September 2014

6.3 Background

The sustainability vision for the West Belconnen development makes direct reference to the use of alternate water sources, where it substitutes for what is traditionally water supplied from the potable network, particularly from the nearby Lower Molonglo Water Quality Control Centre (LMWQCC) that treats a significant portion of Canberra's wastewater. Additionally, the Green Communities rating tool rewards potable water demand reductions and replacement through stormwater harvesting and treated effluent reuse.

The approach to developing a water sensitive urban design vision and an integrated set of (storm, potable and reused) water systems for West Belconnen has been to develop two scenarios/approaches that were derived with reference to the Green Star Communities guidance manual, planning requirements in ACT and NSW (in particular the ACT WSUD Code), and a review of international water sensitive urban design practices and research. The vision development resulted in setting specific quantitative objectives around stormwater volume and quality management and recycled water use/potable demand reduction that were modelled. In turn, modelling as to how to be able to meet these objectives has highlighted a number of water management needs, and, specifically, the possible extent of pathways for the use of alternate water sources necessary to provide the required site water balance and quality targets. However, there are a number of issues that need to be addressed to enable the extent of water recycling proposed to date:

- Typically the driver to use 'alternate' water sources, such as the use of rainwater, stormwater or treated effluent for domestic use or open space irrigation purposes, stems from the desire or need to lessen the demand and reliance on a community's potable water supply. The rationale is that, over time, a diverse and integrated water system would enable the current drinking-water supply system with an increased longevity
- In general, such a philosophy is considered as a sustainable one; this is exacerbated by the point that the majority of Australia's population lives in coastal areas where storm and treated wastewater is discharged to ocean environments without any real benefit, and so capturing and reusing these resources can provide new benefits. However the ACT, as an in-land and land-locked jurisdiction, and drains and has its treated wastewater discharged to river systems where the water is used for recreational, environmental and irrigation purposes downstream. Hence determining the 'right', *i.e.* most sustainable, balance of stormwater flow management and treated effluent reuse will require a truly integrated water system assessment that considers downstream benefits supported by current water and wastewater systems particularly in the ACT
- Additionally, a barrier in the ACT is that the Independent Competition and Regulation Commission (ICRC, 2012) has recommended that, mainly on economic grounds, there should be no more public investment in alternate water supply systems "now", and noting that the ACT Government has agreed to the recommendation.

Having determined the types of alternate water sources and uses that would be critical to deploy to meet, in particular, the *Green Star - Communities* and WSUD Code sustainability requirements, the focus of the following sections is on:

- Reviewing the appropriateness of using the various alternate water sources for particular uses, with a particular emphasis on determining whether and/or how the health risks to those exposed or using the water may need to be managed
- Reviewing the ACT and NSW planning requirements around the use of alternate water sources and what may be required to see these met.

6.4 Health risk assessment and management requirements

Both NSW and the ACT have various rules and requirements in relation to the use of recycled water that generally have health-risk management principles underlying them. These include having approved or restricted uses for, say, treated effluent or stormwater from certain systems, and/or outlining the assessment and management conditions that need to be met to enable certain uses. Some of these planning contexts are outlined below.

6.4.1 ACT context

The *Public Health Act 1997* requires that users of alternate water sources do not create an "unhealthy condition". ACT Health generally uses the *Australian Guidelines for Water Recycling* (2006, from here on referred to as AGWR) to assist define what would constitute an unhealthy condition and what management is required to enable alternate water resources to be used. When it is proposed that alternate water sources are to be used for occupational (*e.g.* firefighting) or commercial food producing endeavours, the *Food Act 2001* (outlining that food must be of a quality fit for consumption) and the *Work Health and Safety Act 2011* requirements would also need to be addressed. The *ACT Wastewater Reuse for Irrigation Environment Protection Policy 1999* also applies, as it recognises and describes health and environmental impact management needs.

The **Lower Molonglo Water Quality Control Centre's** treated effluent is able to be used for a variety of uses where public access can be restricted, and, where water is to be stored for periods before use, adequate chlorine (disinfection) residual can be maintained. At the time of this report, ACT Health recognises the allowed uses of LMWQCC effluent for:

- Construction sites (*e.g.* concrete batching, dust suppression and vehicle wash down)
- Irrigation of access controlled public sites
- Golf courses (*e.g.* irrigation, water hazards, *etc.*)
- Irrigation of commercial turf
- Drip irrigation of non-food crops
- Water features (with appropriate disinfection)
- Commercial landscaping.

As a point of comparison, the EPA Victoria *Guidelines for Environmental Management – Use of Reclaimed Water* (2003) has developed criteria for four classes of reclaimed water; classes range from A to D. The classes are graded on the basis of levels of pathogen reduction, physical-chemical water quality and *E. coli* limits, and other specific measures known to remove pathogens. For example, the highest graded water quality is Class A reclaimed water: its uses include recreational watering without restrictions on public access or direct irrigation of food crops that may be consumed raw. Further, the Queensland *Water Quality Guidelines for Recycled Water Schemes* (DEWS, 2008) categorises water quality in five classes from A+ to D. Performance values for each class have three values that are set from a number of points in time. The values are the short term/sample value, the resample value and the annual value. The short term sample triggers the subsequent resample which produces the resample value that must be achieved. The annual value must be achieved after an approved recycled water management plan has taken place and at each subsequent month after that.

The recycled water quality criteria that are specified in the Victorian and Queensland guidelines are summarised in Table 34, and compared against the treated effluent targets that are achieved at the LMWQCC. This comparison confirms that the allowed uses of LMWQCC effluent are broadly consistent with health risk management approaches from other jurisdictions, and that without additional treatment or management, LMWQCC effluent is not currently allowed for:

- At domestic properties
- For irrigation of foods that may be consumed uncooked
- In swimming pools and spa water
- In water features without disinfection
- For any application at childcare and aged care facilities.
- The treated effluent must not be used for drinking purposes or direct human contact.

In the case of **stormwater** harvesting, there are precedents in the ACT where schemes are in place to enable harvesting of stormwater from collection ponds and use it to irrigate public open space and sporting facilities (managed by TAMS). Again, the health-risk management requirements outlined in AGWR that take into account the intended uses of the stormwater would need to be demonstrated and agreed with ACT Health prior to any new scheme being developed or operated.

The use of **rainwater** tanks for domestic irrigation and use is common around Canberra. The *Rainwater Tanks – Guidelines for residential properties in Canberra* (ACTPLA, 2010) provides guidance on appropriate management and use of rainwater for the resident. There is no legislated health requirement pertaining to rainwater use however the guidelines do:

- Suggest that if you are considering installing a rainwater tank you should consult ACT Health,
- State that rainwater should not be used for drinking purposes when a reticulated potable supply is readily available, and
- Provide tips for maintaining tanks to best manage water quality.

6.4.2 NSW context

The *Interim NSW Guidelines for Management of Private Recycled Water Schemes* (Department of Water and Energy, 2008) is applicable and relates to the requirements for setting up and establishing any type of treated effluent, stormwater or other alternate water use scheme. The situation is not dissimilar as for the ACT, in that NSW Health endorses the use of the AGWR. The *Public Health Act 1991* sets NSW Health the task of regulating the monitoring and performance of recycled water schemes in the interest of public health. The relevant conditions of the *Occupational Health and Safety Act 2000* and the *Food Act 2003* may need to be met depending on the intended uses of the alternate water sources. The Department of Environment and Conservation's (2004) *Environmental Guidelines: Use of Effluent by Irrigation* requirements must also be met.

Table 34 Comparison of recycled water quality at LMWQCC against Victoria and Queensland recycled water classes and allowed uses

Class	LMWQCC	Victoria			Queensland	
	Target 90th percentile concentrations	Water quality objectives	Treatment processes	Range of uses	Annual value required for 95% of samples taken	Water class for irrigating minimally processed food crops
A+		-	-	-	▪ <0.5 mg/L CL_2 residual ▪ <1 pfu/100mL Clostridium perfringens ▪ <1 pfu/100mL F-RNA bacteriophages ▪ <1 pfu/100 mL somatic coliphages ▪ <1 cfu/100 mL *E.coli* ▪ Turbidity < 2 NTU	▪ Crops with produce grown on or near the ground normally eaten with skin removed e.g. rockmelon ▪ Crops grown on or near the ground other than produce normally eaten with skin removed e.g. broccoli, tomato ▪ Crops with produce grown away from the ground e.g. apple, olive ▪ Crops for produce grown in hydroponic conditions e.g. herbs, lettuce
A		▪ <10 *E.coli* org/100 mL ▪ Turbidity < 2 NTU ▪ <10/5 mg/L BOD/SS ▪ pH 6-9 ▪ 1 mg/L CL_2 residual (or equivalent disinfection)	Tertiary and pathogen reduction with sufficient log reductions to achieve: - <10 *E.coli* per 100 mL - <1 helminth per litre - <1 protozoa per 50 litres - <1 virus per 50 litre	▪ Urban (non-potable): with uncontrolled public access ▪ Agricultural: e.g. human food crops consumed raw ▪ Industrial: open systems with worker exposure potential	▪ <10 cfu/100 mL *E.coli*	▪ Root crops e.g. onion, carrot ▪ Crops grown on or near ground, drip irrigation only

Class	LMWQCC	Victoria			Queensland	
	Target 90th percentile concentrations	Water quality objectives	Treatment processes	Range of uses	Annual value required for 95% of samples taken	Water class for irrigating minimally processed food crops
B	***Approximate Class:*** - <8/10 mg/L BOD/SS - <0.4 mg/L TP - <550 mg/L Dissolved solids - <200 cfu/100 mL thermotolerant coliforms	▪ <100 *E.Coli* org/100 mL ▪ pH 6-9 ▪ <20/30 mg/L BOD/SS	Secondary and pathogen reduction (including helminth reduction for cattle grazing use schemes)	▪ Agricultural: dairy cattle grazing ▪ Industrial: e.g. wash-down water	- <100 cfu/100 mL *E.coli*	▪ Crops with produce, other than rockmelon, grown on or near the ground normally eaten with skin removed; spray irrigation ▪ Crops with produce grown away from ground normally eaten with skin removed e.g. avocado, banana; spray irrigation ▪ Crops with produce grown away from ground normally eaten with skin remaining; drip, flood or furrow irrigation
C		▪ <1,000 *E.Coli* org/100 mL ▪ pH 6-9 ▪ <20/30 mg/L BOD/SS	Secondary and pathogen reduction (including helminth reduction for cattle grazing use schemes)	▪ Urban (non-potable): with controlled public access ▪ Agricultural: e.g. human food crops cooked/processed, grazing/fodder for livestock ▪ Industrial: systems with no potential worker exposure	<1,000 cfu/100 mL *E.coli*	▪ Crops with produce, other than rockmelon, grown on or near the ground normally eaten with skin removed; subsurface, drip, flood or furrow irrigation ▪ Crops with produce grown on or near the ground normally eaten with skin remaining; subsurface irrigation only ▪ Crops with produce grown away from ground normally eaten with skin removed e.g. avocado, banana; drip, flood, furrow or subsurface irrigation

Class	**LMWQCC**	**Victoria**			**Queensland**	
	Target 90th percentile concentrations	**Water quality objectives**	**Treatment processes**	**Range of uses**	**Annual value required for 95% of samples taken**	**Water class for irrigating minimally processed food crops**
						▪ Crops with produce grown away from ground normally eaten with skin remaining; subsurface irrigation
D		▪<10,000 *E.Coli* org/100 mL ▪pH 6-9 ▪<20/30 mg/L BOD/SS	Secondary	▪ Agricultural: non-food crops including instant turf, woodlots, flowers	<10,000 cfu/100 mL *E.coli*	

6.5 Preliminary health risk and management needs assessment

In general, the existing legislations do not prohibit any specific alternate water systems, rather they aim to ensure that it can be assessed and demonstrated that the right controls and systems are in place to manage the water quality and health risks for the intended uses. ACT Health and NSW Health each have specific requirements and referral powers to determine whether those risk management conditions would or can be met, depending on the type of system.

Management, monitoring and control of water quality are essential requirements when using recycled water in any part of Australia. The *AGWR* has at its core a health-informed risk management approach, whereby it advocates that treatment, monitoring and use plans are developed in a way that meets local jurisdictional requirements and at the same time demonstrates that the water quality would pose a very low to negligible health risk to users and the general population. While it is up to specific jurisdictions to determine the appropriate health-based water quality objectives for their own circumstances, the AGWR suggests that a target of achieving $< 1 \times 10^{-6}$ Disability Adjusted Life Years (DALY) *p.a.* for any individual exposed to the water would be appropriate. The DALY is a way to measure the burden of disease on a person or a community, and adopting the mentioned target broadly means that the presence of pathogens and chemicals in the recycled water should be managed in a way to not result in a greater chance than '1 in a million' in a year that someone exposed to that water would spend more than a day with illness or be otherwise harmed.

A 'screening level' health risk assessment has been undertaken to assist to identify the feasibility (from a health compliance perspective) and management requirements that may need to be adopted to enable various alternate water resources and uses at the West Belconnen development. The main focus of water quality risk assessment is on microbial pathogens that may be present in the water, as they pose a greater hazard to humans, generally, than chemicals. To that end, it is common to focus initially on assessing the presence and risk posed by three reference pathogens known to be common in water systems and that are hazardous to human health:

- *Campylobacter* (as a reference bacteria)
- *Cryptosporidium* (protozoa)
- *Rotavirus* (virus).

The screening level assessment, undertaken mainly with reference to the *Australian Guidelines for Water Recycling*, has involved an assessment of the 'typical' concentrations of these pathogens in various types of water resources, how effectively they can be removed by various treatment or exposure control measures, the level of exposures to various community members, and the ensuing health risk/disease burden. The table provided below summarises the various planning and management needs that may need to be implemented to make the schemes viable from a health management perspective.

	Source	Use	Standard/existing water quality controls	Possible additional 'barriers' required to appropriately manage health risks (subject to further assessment)	Indicative assessment of feasibility*	Further comments
[1]	**LMWQCC**	"Third pipe" to the household (toilet flushing, laundry, cooling, irrigation)	The LMWQCC employs primary, secondary and tertiary treatment (chlorination) to treat the effluent to meet <200 thermotolerant coliforms/100mL targets (an indicator of the presence of faecal-borne pathogen removal). The plant has proven to be reliable to this target. Supply and use of LMWQCC treated effluent requires an Environment Protection Agreement between ACTEW Water and the recipient outlining the management and water quality conditions that must be met by both parties.	An additional treatment process or step may be necessary particularly to manage risks from human viruses, and a chlorine residual would need to be maintained. This may require diversion of the treated effluent from LMWQCC prior to chlorination to enable the additional treatment (perhaps ultrafiltration + UV) and then chlorination and control of a chlorine residual through the third pipe network.	🟥	There are examples elsewhere of treated effluent being supplied to homes (e.g. Class A recycled water systems in Victoria supplied by City West Water; Rouse Hill, NSW supplied by Sydney Water to 18,000 homes; Googong, NSW to have recycled water supplied to 16,000 residents). Given the demand to maintain, the new infrastructure requirements, and scheme governance, could be significant.
[2]		Irrigation - community food garden		As for [1] + education of residents about the importance of washing, peeling, cooking vegetables (especially lettuce, cabbage, root vegetables) before consumption <u>OR</u> As for [1] + allow only tree crops (where produce is grown 1-2 m above ground) to be grown in the garden <u>OR</u> Allow only a commercial food enterprise to be located in the community that manages the undertaking of onsite washing, storage and/or processing of the food prior to sale or distribution for consumption	🟧	In Victoria recycled water treated to 'Class A' standard can be used for food crop irrigation for foods consumed raw. It is to be determined how LMWQCC's effluent quality compares to the 'Class A' requirements in other jurisdictions however its currently 'allowed' uses and quality targets compare to lesser (e.g. Class B or C in Victoria) treated effluent categories with more use restrictions (such as only irrigating tree crops). That said, LMWQCC effluent is already allowed for commercial food crops and is used for vineyard applications.

	Source	Use	Standard/existing water quality controls	Possible additional 'barriers' required to appropriately manage health risks (subject to further assessment)	Indicative assessment of feasibility*	Further comments
[3]		Firefighting		As for [1]	🟧	Treated effluent is already allowed for firefighting in other jurisdictions. However, it is dependent on satisfying the necessary water quality criteria set in AGWR; for example Class A treated effluent is allowed for firefighting in Victoria, while in NSW a Memorandum of Understanding exists between Sydney Water and the Fire & Rescue Services of NSW that sets out the quality and use requirements to be met.
[4]		Public open space/golf course irrigation		None - already an allowed use	🟩	Requires a user agreement to be executed between ACTEW Water and the supplied entity
[5]	**Stormwater**	"Third pipe" to the household (toilet flushing, laundry, cooling, irrigation)	The Water Sensitive Urban Design strategy for the site would include a number of measures to promote clean stormwater runoff (design measures to limit the contaminant load entering the water system), as well as treatment via wetlands, pond storages and settling time	Storage (with critical storage times mandated to provide pathogen decay time), perhaps a filtration unit (to control *Cryptosporidium* and *Giardia*) + disinfection by chlorine and maintenance of a chlorine residual	🟥	Semi-centralised capture and reuse of stormwater for domestic use at this scale is not the norm, even in relatively modern water recycling contexts.
[6]		Irrigation - community food garden			🟧	There are examples in Canberra of community food gardens that use stormwater for irrigation. The stormwater quality and treatment measures would need to be demonstrated to comply with the requirements of the AGWR.
[7]		Firefighting			🟧	There is no precedent of urban stormwater being used for fire-fighting in Australia. The stormwater quality and treatment measures would need to be demonstrated to comply with the requirements of the AGWR, and agreed with the ACT Fire & Rescue Service.

	Source	Use	Standard/existing water quality controls	Possible additional 'barriers' required to appropriately manage health risks (subject to further assessment)	Indicative assessment of feasibility*	Further comments
[8]		Public open space/golf course irrigation		None - there are existing stormwater harvesting and reuse schemes in the ACT and NSW	🟩	Similar schemes are operated and managed by Territory and Municipal Services. If this model were applied again, it would require the infrastructure and operations to be managed via a user agreement to be executed between TAMS and the supplied entity
[9]	**Rainwater tanks**	Domestic (toilet flushing, outdoor only)	Existing plumbing/building codes and ACT and NSW guidelines identify good practice in terms of keeping tanks closed, preventing birds roosting on roofs, keeping vermin out of tanks, desludging, *etc.*	None	🟩	Common use and a central part of the WSUD Code. *The Rainwater Tanks – Guidelines for residential properties in Canberra* (ACTPLA, 2010) provides guidance on appropriate management and use of rainwater for the resident. There is no legislated health requirement pertaining to rainwater use however the guidelines do: - suggest that if you are considering installing a rainwater tank you should consult ACT Health, - state that rainwater should not be used for drinking purposes when a reticulated potable supply is readily available, and - provide tips for maintaining tanks to best manage water quality. Rainwater to hot water systems are already in place in some rural properties in the ACT and NSW, and some developments recently in Brisbane and other cities in Australia have incorporated such systems. *Refer to Section 3.3.3for a discussion of the recent health risk studies and management measures that may be necessary for rain-to-hot water systems.*
[10]		Domestic (hot water supply)		Require that all hot water units heat water to > 60°C and maintained at that temperature for a minimum time (to be determined). Possibly on-site treatment by filtration or UV disinfection at each household (to be determined).	🟨	

*** From a health risk management perspective - the following legend applies:**

🟥	Further work required to determine feasibility: Rarely used in Australia, significant and/or complex new infrastructure and monitoring/control systems required to manage health risks
🟧	Probably feasible: Precedents exist elsewhere in Australia, additional infrastructure and/or monitoring/control systems required to manage health risks
🟩	Highly feasible: Already wide-spread in the ACT, no or low level of additional treatment infrastructure required to manage health risks

6.6 Alternate water sources – other planning and regulatory issues

In addition to the health risk management requirements, there are other regulatory, planning and economic considerations on which decisions about using alternate water sources need to be based. Some of these are introduced below, noting that this is not an exhaustive discussion and there are likely to be other considerations as well to be documented through the further work still required informing the water management strategy for the development.

6.6.1 Regulation of non-potable water schemes

There are separate regulators in each of the ACT (Independent Competition and Regulatory Commission, ICRC) and NSW (Independent Pricing and Regulatory Tribunal, IPART). Nominally it makes sense that an agreement can be reached to see that a single regulator would have oversight of a non-potable water supply system servicing West Belconnen. Given that the new community will be connected and integrated with ACT infrastructure, services and other networks it would make sense that the ICRC was the nominee; however this requires discussion and negotiation with the relevant NSW and ACT authorities. Depending on how the cross-border regulation issues are settled will determine the licensing and governance arrangements that would best suit the West Belconnen alternate water systems. Some commentary on license arrangements in NSW and ACT follows.

6.6.2 Licensing and operating

In the ACT, the *Utilities Act 2000* is administered by the ICRC and regulated by the Environment and Sustainable Development Directorate. Currently ACTEW Water is the only licensed water utility in the ACT. ACTEW Water is likely to be the entity that would run any effluent reuse scheme from LMWQCC into the West Belconnen community homes; as such a scheme would come under the *Utilities Act*, and has to have a licensed operator. In regard to stormwater harvesting the Territory and Municipal Services may soon be recognised as a utility for the purposes of managing the harvesting schemes.

In NSW, the *Water Industry Competition Act 2006* and regulations have been developed to"…facilitate the development of infrastructure for the production and reticulation of recycled water; and for other purposes" and would apply. The act requires that a non-utility entity in NSW (and noting that neither ACTEW Water nor any ACT Government entity is recognised as a utility in NSW) obtains a WICA licence for the delivery, operations, management and commercial aspects associated with running the private alternate water supply scheme.

In general, alternate water supply licensees in any jurisdiction would be required to develop and implement water quality and use management plans that meet the various components of the frameworks set out in the AGWR and be audited against these annually or on an as agreed basis.

6.6.3 Economics

In the 2008 ICRC *Final Report and Price Determination* the ICRC stated "ACTEW must provide bulk water and reuse water on the basis that customers pay at least the avoidable cost of supply, and less than the stand-alone cost of supply. Furthermore, bulk water prices should be set on the basis of the following principles:

- Prices should seek to recover avoidable costs.
- Prices should provide for a fair and reasonable rate of return on capital invested.
- Prices should discourage uneconomic bypass.
- Prices should be set according to a well-defined and clearly explained methodology."

The ICRC would likely take the view that they would not want potable water users cross-subsidising users of an effluent reuse scheme. In which case any effluent supply scheme would need to be established in a way that recovered all costs (lifecycle costs) and gave ACTEW Water (or any other operator) a return on the assets employed to deliver this service. Failure to do this would result in the cross subsidy the ICRC wants to avoid.

In the ACT at the moment private investment and delivery of a non-potable water system can only occur if that private entity be recognised as a utility under the *Utilities Act 2000*, and the administrative and other requirements imposed on such a utility would be a major deterrent to it being a sustainable enterprise. In NSW the WICA licensing scheme encourages competition and enables private service providers to determine the feasibility of placing and running a non-potable water scheme based on market demand and at the provider's own risk. Such a system may find place in the ACT over time and could address the ICRC's reluctance to have any public investment in non-potable water infrastructure for the time being; however the legislative and policy instruments do not exist and would need to be in place relatively soon to be able to be relied upon for the West Belconnen development.

6.6.4 Triple Bottom Line

The ACT Government provides advice on how to assess sustainability (Chief Minister and Treasury Directorate, *n.d.*) and conduct triple bottom line assessments (Chief Minister and Treasury Directorate, 2013). These techniques need to be used when assessing the costs and benefits of alternate water use (and for several other facets) of the West Belconnen community development, *i.e.* in general the West Belconnen master plan needs to reflect the optimal outcomes in terms of environmental, economic and social sustainability.

6.7 Recommendation

Identifying opportunities and roles for the deployment of alternative water resources (stormwater, treated wastewater, *etc.*) was a key component of the study scope. Decisions to implement alternative water and water reuse schemes need to be based on a well-rounded economic basis, *i.e.* considering and providing for a net social, financial and environmental benefit, and not just on the rationale to reduce reliance on the primary potable water resource. This is particularly so in the ACT where there has been a recent significant investment in potable water supply security infrastructure.

The nearby Lower Molonglo Water Quality Control Centre (LMWQCC) was identified early in the study as a potential supplier of treated wastewater effluent for non-potable water uses (as there are already similar schemes in place). However, a stormwater harvesting scheme has been preferred in the development of water management strategies at West Belconnen. The rationale was based upon:

- Determining (through modelling) early that the surplus stormwater runoff being generated at the site would require novel management and disposal solutions, and there was an opportunity associated with this for beneficial reuse
- It is likely that either stormwater or LMWQCC effluent reuse would require similar additional infrastructure to distribute the water and to meet the health risk management requirements of the *Australian Water Recycling Guidelines*.
- If the LMWQCC effluent were used, the stormwater management infrastructure would need to include additional high-flow pipelines running down the river corridor and/or other scour protection measures in any case, to mitigate high flows running down the river corridor
- The LMWQCC effluent currently contributes to controlled environmental flows in the Murrumbidgee River for downstream irrigators. Using it on the development site would have other water balance accounting implications for the ACT under the Sustainable Diversion Limits set out in the Murray-Darling Basin Plan.

7.0 Testing and modelling the structure plan

7.1 Hydrological modelling and flood attenuation

Hydrological modelling was important on this project to ascertain the current hydrology of the site, the impact of the proposed development on peak flows and support the definition of the mitigation strategies that would deliver on the environmental objectives for the project.

The hydrological investigation on this project was shared between Brown and AECOM. Brown carried out the catchment delineation and base modelling. AECOM was responsible for developing the appropriate detention basin provisions and integrating these in the IWCM strategies on the project.

7.1.1 Catchment delineation

The site comprises a large number of catchments and sub-catchments (Figure 30). For more information about the catchment delineation and details about areas, slope, *etc*. refer to the Brown Consulting (2014) report and drawings.

7.1.2 Hydrological modelling

The hydrological model for the project was developed using XP-RAFTS. The model parameters were selected to reflect:

- The topography of the site
- The proposed land uses as described in the February 2014 Draft Structure Plan (at Appendix b)
- Recommended parameters as specified in ACT codes and standards.

For more information on the hydrological model, please refer to the Brown Consulting (2014) report and drawings.

7.1.3 Detention basin and flood attenuation provisions

Using the hydrological model from Brown Consulting (2014) that included both pre-development and post-development flows, the attenuation requirements were determined using a hydrograph method which is described below.

The method is used for preliminary, simplified calculation of stormwater attenuation or detention volumes based on a methodology developed by Bewsher (1993) and subsequently refined by Cardno Willing (2002) and tailored to the West Belconnen context. The method compares the pre-development and post-development hydrographs and calculates the total volume corresponding to the increase in runoff over time. The detention requirements are determined as corresponding to this total volume. The method is illustrated in Figure 38.

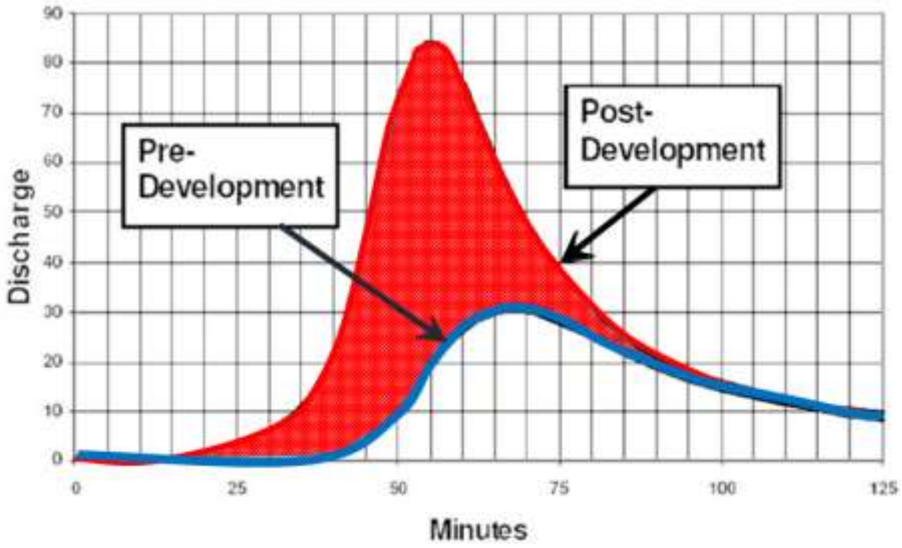

Figure 38 **Hydrograph method to estimate detention volume requirements**

By applying this approach across all sub-catchments of the West Belconnen site, it was possible to establish a regression curve that helps statistically predicting the storage requirement based on the upstream catchment area. Figure 39 below provides the regression curve for the West Belconnen project.

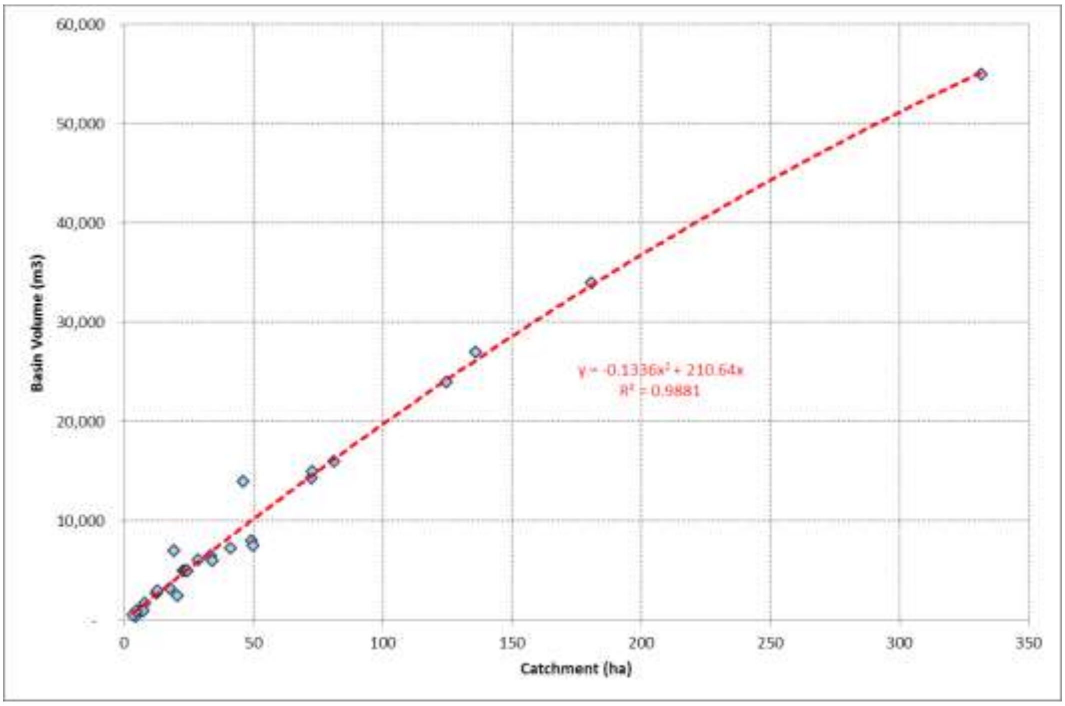

Figure 39 West Belconnen stormwater attenuation regression curve

The method was selected for its ability to efficiently produce at this early stage of project planning the preliminary storage requirements for the site. It is important to note that these preliminary results will require refining and confirmation as the urban planning and design progresses.

More specifically, the following parameters will be critical as they become available:

- Basin outlet design
- Stage/storage curves
- Pit/pipe network in the upstream catchments
- Overland flow configurations in the upstream catchments).

Caution needs to be exercised in reusing any of the information provided here for any other purpose than that of master planning.

7.1.4 Impact of extreme storms

During the consultation and peer review process, one of the questions raised (see Section 9.0) related to better understanding the impact of extreme storms on the Murrumbidgee River corridor.

The assessment of events larger than the 100 year ARI presented here uses an estimate of the Probable Maximum Precipitation (PMP). The PMP is "...the theoretical maximum precipitation for a given duration under modern meteorological conditions." Typically this is used by hydrologists, who use a PMP magnitude, plus its spatial and temporal distributions, to calculate the Probable Maximum Flood (PMF) for the catchment of a dam. The PMF is used to design the dam. The PMP is a very rare and unlikely event[23].

The objective of the PMF calculation is to ensure that a dam or similar structure is strong enough or sufficiently designed such that human life or essential infrastructure is not endangered should a PMF occur. The PMF is generally used to locate critical infrastructure such as electricity, telecommunications and hospitals. For the purposes of this assessment, it is also worth considering the impacts of flows greater than the 100 year ARI event but less than the PMF.

Potential infrastructure impacts

The PMF may be taken into consideration in the design of flood attenuation structures within the development. These flood attenuation structures should be designed such that if flood volumes exceed the PMF, the structures do not fail or create flows that endanger human life or essential infrastructure. Consideration should be given to

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[23] See notes by BoM at: http://www.bom.gov.au/water/designRainfalls/pmp/, accessed September 2014

ensuring that spillways can safely pass flows above the 100 year ARI, and that overland flow paths should be provided in the master planning process to safely convey the resultant flows.

Potential environmental impacts

Gullies and streams can be eroded and damaged by large flows. However, the PMP and PMF are not usually considered in an assessment of environmental impacts. The flows of most importance to gullies and streams are the channel forming flows, typically considered to be the bank-full flow, and typically corresponding to flows that occur in a 1 to 2 year recurrence interval. Larger flows do impact sediment transport in streams, but because they occur infrequently, they are responsible for a smaller proportion of the sediment transport in the long term.

Potential impacts on the environment of flows greater than the 100 year ARI and up to the PMF would include erosion, sedimentation and loss of habitat. Impacts of the PMF on the environment are not normally considered in environmental impact assessments because the frequency of disturbance caused by the PMF is so low that the intervals between events are much longer than planning timeframes. Providing engineering or interventionist structures to protect the environment from the PMF would probably require “over-engineered” structures, which themselves would generate adverse impacts on the environment. Therefore, impacts to the environment resulting from a PMF should be managed on a case-by-case basis, and rehabilitation measures determined as warranted by the damage caused. In the unlikely event of the PMF occurring, damage may be widespread and any disaster recovery program will need to prioritise rehabilitation requirements at that time based on the required timeframes and available resources.

PMF flows

A preliminary assessment was made to understand the order-of-magnitude of the peak flows that may occur at example locations throughout the site in the Probable Maximum Flood event.

It should be noted that at this stage of design development it would not be appropriate to definitively estimate peak flow rates for design purposes. The flow estimates given below will change as catchment details such as the configuration of pit and pipe networks, detention basins are surveyed and outlet structures designed, overland flow paths and catchment imperviousness estimates are refined in subsequent design stages.

Table 35 Probable Maximum Flood peak flow estimates

Example Catchment	1 year ARI peak flow (m^3/s)	100 year ARI peak flow (m^3/s)	PMF peak flow (m^3/s)	% increase on 100 year ARI
I1.3	0.7	12	57	+375%
Y	1.8	6	11	+83%
B	5.1	21	32	+52%
M	4.8	18	24	+33%
X	1.4	5	6	+20%

The above flow estimates serve to demonstrate the non-linear nature of the catchment response to rainfall, and highlight the variability of the flow estimates. This variability is generally a function of

- Catchment area
- Slope
- The travel time between catchments (the routing or “lag” time)
- Flood storage in detention basins
- Outlet configuration at detention basins

PMF peak flows vary between small increases to very substantial increases in peak flows.

Impact of the proposed development on the PMF

By adhering to the principle of maintaining the natural landscape, the proposed development will not impact the PMF extent or magnitude estimates. This is because by definition a PMF estimate assumes that all grounds are fully saturated, meaning that they are effectively acting as 100% impervious surfaces in any case.

Mitigation options

The following options were considered as potential means to mitigate the damaging impact of flows above the 100 year ARI:

- Divert flows above the 100 year ARI via roads to locations of safe discharge
- Provide additional flood storage
- Provide energy dissipation structures in the gullies
- Level spreaders across the contours (as berms) to dissipate large flows
- Major diversions using pit and pipe infrastructure

In assessing each of the above options, it was considered that the adverse consequences that would result from these interventions would outweigh the potential benefits. The adverse consequences include:

- Flow concentration - unduly concentrating flows will acutely focus erosive energy and potential in specific areas
- Over-engineering – large engineered reinforced landscapes to protect against erosion from large and infrequent events would create poor landscape and urban design outcomes, for situations that might never arise during the lifespan of the existing infrastructure.

  Cost prohibitive - all of the options considered would involve substantial expense for events of very low likelihood, that present a very low risk. It is expected that these would be cost prohibitive, the construction of such interventions would be directly damaging to the local environment and resource intensive.

Therefore, no specific mitigation measures are recommended for the PMF.

7.2 Stormwater harvesting scheme modelling

As part of this investigation, it was important to characterise and test the potential for stormwater harvesting as it was identified early in the study as potentially central to meeting the adopted environmental and water management objectives.

There were two distinct stormwater harvesting scheme propositions:

- A large, centralised stormwater harvesting scheme (*i.e.* the ‘aspirational’ scenario)
- A smaller, decentralised stormwater harvesting scheme (*i.e. the* ‘intermediary’ scenario).

They are presented below.

7.2.1 Larger, centralised stormwater harvesting scheme

For the centralised stormwater harvesting scheme proposal, the modelling approach relied on:

- Estimating total demand for the entire urban development project based on density and public open space planning
- Developing a high level simplified water balance model to estimate the storage requirements to achieve reasonable level of reliability
- Distribute the necessary total storage volume across the site based on the respective catchments areas draining to the various basins
- Consolidating the storages into stormwater harvesting ‘super ponds’ where possible.

The water balance modelling was carried out using a MUSIC model for the project site.

Modelling assumptions

For the MUSIC water balance model of the site, the following assumptions were used:

- Catchment area: 1,200 ha
- Imperviousness: 64% (based on the February 2014 Draft Structure Plan)
- Demands for stormwater reuse as per Table 36 below.

Table 36 Household and community water use at dwellings

Use	Daily household (L/d)	Annual household (L/year)	Daily all residents* (ML/d)	Annual all residents* (ML/year)
Internal demand (non-potable)	147	53,655	1.764	643.86
Internal demand (+hot water)	254	92,710	3.048	1,112.52
External	67	24,455	0.804	293.46

** assumes 12,000 dwellings*

Results of the modelling are presented below.

Storage requirements

The water balance model was used to test:

- A range of storage capacities from 20,000 m^3 to 150,000 m^3.
- Changes in reliability of supply depending upon whether the stormwater was providing the supply of hot water or cold non potable water uses only (*i.e.* laundry, garden, toilet flushing)
- The potential impact of seepage losses through the natural heavy clays of the site (and the merits of lining the ponds).

In all stormwater harvesting schemes, as the capacity for storage is increased, the gain in reliability is not linear. As the storage capacity increases, other parameters affecting the overall reliability of the system become more limiting (including total annual rainfall, seasonality of rainfall, bypass on harvesting systems, *etc.*)

The main objective of the water balance modelling is to determine the optimum in storage capacity along the ‘diminishing return’ curve. The diminishing return curve for the West Belconnen project is presented below.

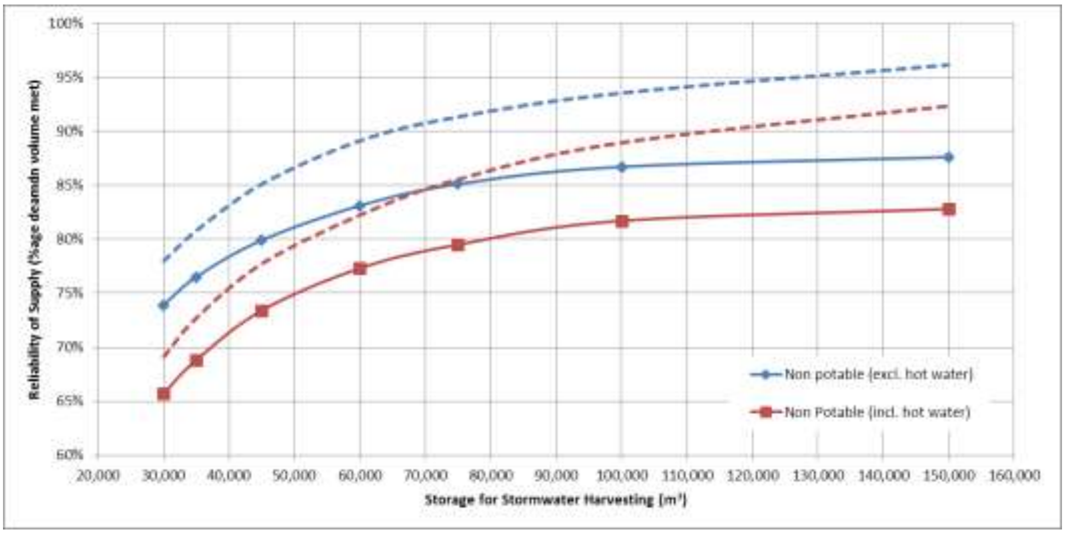

Figure 40 Centralised stormwater harvesting water balance at West Belconnen

A number of observations can be made from the above figure:

- It is possible to propose a stormwater harvesting scheme is high reliability of supply
- The optimum capacity for stormwater harvesting storage is between 100,000 and 110,000 m^3.
- Beyond 110,000 m^3 there is little gain in reliability of supply
- The loss due to seepage and infiltration (difference between the solid and dashed line) is significant: approximately 6-7% (further discussed at Section 10.2).

Distributing the storage requirements across the site

The storage for stormwater harvesting initiatives will be provided at multiple levels:

- Rainwater tanks at a household level
- Stormwater harvesting system tanks

- Ponds and wetlands

Rainwater tanks at a household level can reasonably be expected to have a capacity of 2-3kL. Based on the operational requirements and guidelines for stormwater harvesting schemes, the recommendation is for stormwater tanks to have a minimum capacity of 16 ML on this project. The difference needs to be provided in the distributed ponds across the site. Table 37 summarises the distribution of stormwater harvesting storage needs across the entire site for the larger scale 'aspirational' scenario.

Table 37 Distribution of storage provisions for the centralised stormwater harvesting scheme

Parameter	Derived from	Value	Unit
Total storage requirement:	Water balance model	**110,000**	**m^3**
Household Storage:	No. dwellings	12,000	no.
	RWT capacity	3	kL
	Usable portion	70	%
	Capacity	*25,200*	*m^3*
Stormwater harvesting system tanks:	No.	2	
	Unit Capacity	8,000	m^3
	Capacity	*16,000*	*m^3*
Pond storage requirements:	*Capacity*	***68,800***	***m^3***

The subsequent distribution of the pond capacity across the site was done using the respective catchment areas so that storage capacity can be met by adequate harvestable runoff. The distribution across the site was apportioned as per the following:

Table 38 Distribution of storage capacity across catchments

Catchment*	Area (ha)	Storage Capacity (m^3)	Harvesting provision (m^3)
B	48.31	3,400	6,800
C	41.84	2,950	5,900
D	126.25	8,850	17,700
E	140.17	9,800	19,600
M	40.58	2,850	5,700
SAT	57.53	4,050	8,100
JKL	145.92	10,200	20,400
RIY	401.6	28,100	56,200
Total	**1002.2**	**70,200**	**140,400**

* Refer to the WSUD drawing set for the catchment location

7.2.2 Smaller, decentralised stormwater harvesting scheme

The decentralised stormwater harvesting scheme design was more specific. The water balance modelling was carried out to validate the feasibility of a series of local stormwater harvesting schemes. These schemes were defined by where the public open space irrigation demands would be.

Demands were estimated based on irrigation areas. Storages were derived from the footprint of the respective WSUD measures which were determined based on water quality improvement performance requirements. A closer analysis of the location of demand and potential sources of stormwater from the proposed ponds and wetlands helped identify a series of 12 local scale distributed stormwater harvesting schemes centred on the larger WSUD measures of the site. An illustration is provided in Figure 41 below. A high resolution concept is provided in Appendix e.

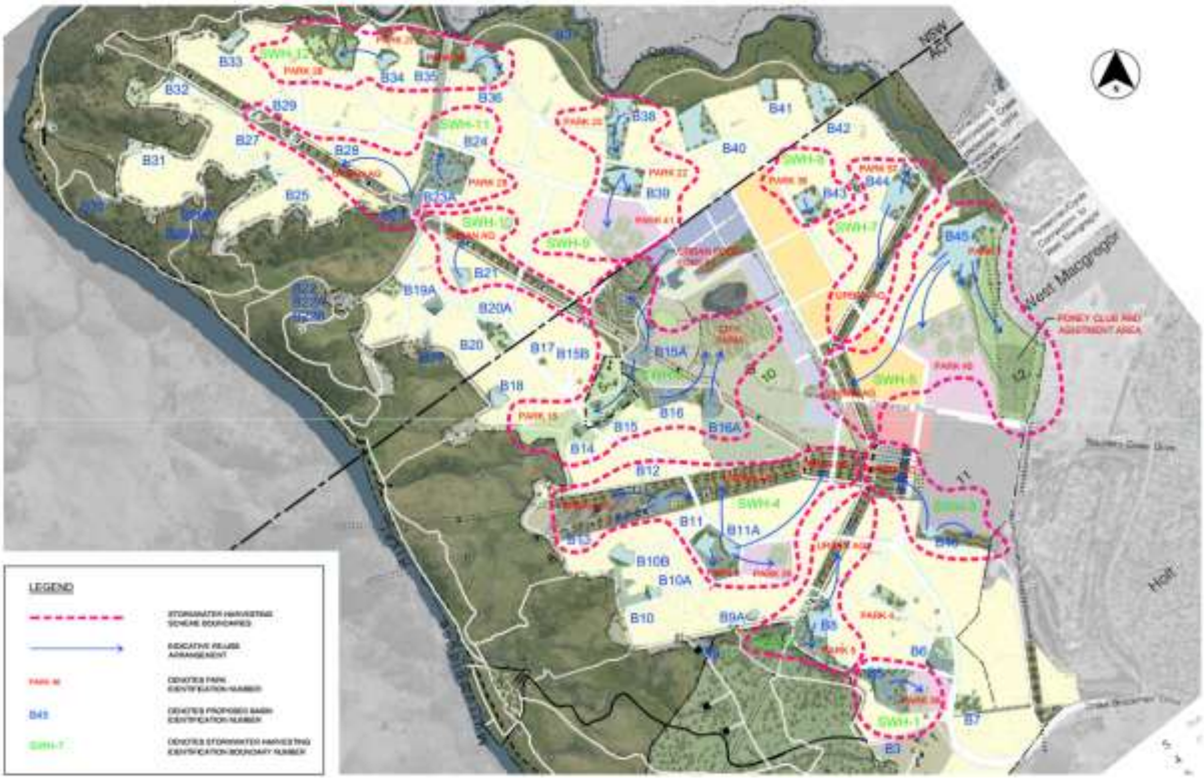

Figure 41 Decentralised local stormwater harvesting schemes option

The distribution of urban parks and other demands across the various schemes provided below:

Table 39 Distributed stormwater harvesting schemes breakdown

Harvesting scheme # (refer to Figure 41)	Users	Total area (ha)	Annual demand (ML)
1	**Total**	**1.2**	**4.70**
	Park 38	1.2	4.70
2	**Total**	**8.8**	**34.50**
	Park 4 & 5	7.1	27.83
	Urban agriculture	1.7	6.66
3	**Total**	**4.1**	**16.072**
	Urban agriculture	4.1	16.07
4	**Total**	**21.17**	**82.99**
	Park 8	3.17	12.43
	Park 39	1.2	4.70
	Urban agriculture	10.4	40.77
	Urban agriculture	6.4	25.09
5	**Total**	**31.04**	**121.68**
	Park 7	2.74	10.74
	Park 40	7	27.44
	Urban agriculture	2.3	9.02
	Pony club + agistment	19	74.48

Harvesting scheme # (refer to Figure 41)	Users	Total area (ha)	Annual demand (ML)
6	**Total**	**27.7**	**108.58**
	Park 15	11.7	45.86
	Urban Food Forest	8	31.36
	City Farm	8	31.36
7	**Total**	**6.38**	**25.01**
	Park 37	1.88	7.37
	Urban agriculture	4.5	17.64
8	**Total**	**0.44**	**1.72**
	Park 36	0.44	1.72
9	**Total**	**7.69**	**30.14**
	Park 23	2.05	8.04
	Park 22	1.64	6.43
	Park 41	4	15.68
10	**Total**	**3.1**	**12.15**
	Urban agriculture	3.1	12.15
11	**Total**	**7.02**	**27.52**
	Urban agriculture	2.6	10.19
	Park 25	4.42	17.33
12	**Total**	**3.1**	**12.15**
	Park 27 + 28	2.13	8.35
	Park 26	0.97	3.80

Table 40 Summary of irrigation demands served by the decentralised system

User	Total area (ha)	Annual demand (ML)
Park 04 & 05	7.1	27.8
Park 07	2.7	10.7
Park 08	3.2	12.4
Park 15	11.7	45.9
Park 22	1.6	6.4
Park 23	2.1	8.0
Park 25	4.4	17.3
Park 26	1.0	3.8
Park 27 + 28	2.1	8.3
Park 36	0.4	1.7
Park 37	1.9	7.4
Park 38	1.2	4.7
Park 39	1.2	4.7
Park 40	7.0	27.4
Park 41	4.0	15.7

User	Total area (ha)	Annual demand (ML)
City Farm	8.0	31.4
Pony Club	19.0	74.5
Urban Food Forest	8.0	31.4
Urban Agriculture	35.1	137.6

Reliability of decentralised stormwater harvesting schemes

It is important to note that the proposed schemes are not driven by a particular water security or potable water substitution. Instead, the reason for their consideration is to reduce the amount and frequency of urban stormwater excess discharged to the receiving environment.

Typically, a stormwater harvesting scheme is considered most adequate when the supply achieves 75% - 85% of demand being met. If the reliability is lower than 75%, then typically the decision to proceed on the basis of water security or potable substitution does not eventuate. Reliabilities in excess of 85% typically represent a suboptimal scheme where storages have been oversized.

For the schemes considered here, a lesser reliability in excess of, say, 50% may be considered acceptable on the basis that:

- The storage volumes are obtained at no extra cost, given the need for the wetlands and ponds for flood mitigation and water quality improvement anyway
- The schemes provide benefits in terms of meeting environmental impact mitigation objectives.

The results for reliability of supply are provided below:

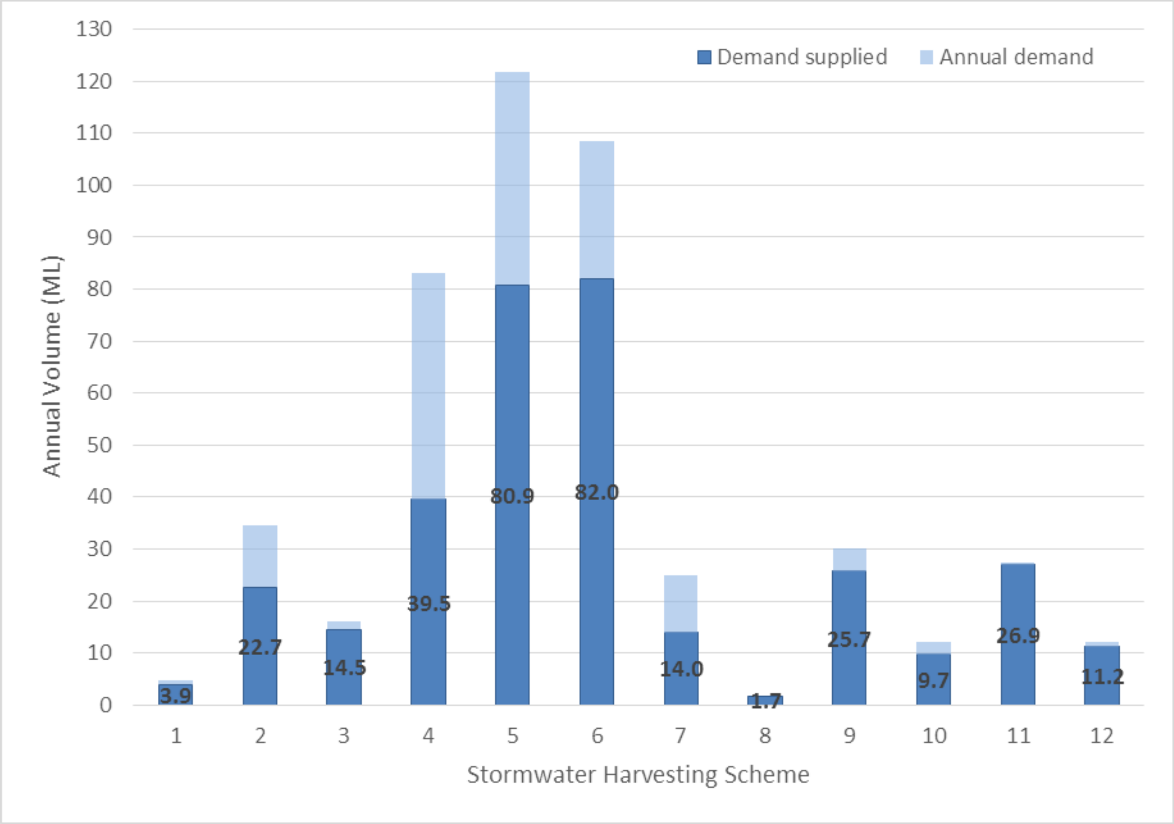

Figure 42 Decentralised stormwater harvesting schemes - reliability

NB: refer to Figure 41 for scheme locations

The reliability of most schemes is quite high and ranges mainly between 65% and 100%. The schemes where 100% reliability is achieved correspond to large catchments and regional WSUD measures with comparatively small nearby irrigation demands.

7.3 Water quality and flow management modelling

The water quality and flow management modelling was carried out using MUSIC v6 software. The base model was developed in line with the ACT WSUD Code parameters for rainfall, runoff and water balance modelling. Water demands at household level and for wider irrigation have been included in line with the relevant sections in this report.

Water quality

The water quality results were generated directly from MUSIC using the treatment train effectiveness calculation which accounts for the total removal of pollutant over the entire train of treatment measures and devices, also accounting for the reduction in pollution associated with any water reuse.

Flow management

The flow management performance criteria included both volume reduction and number of runoff days. The volume reduction is directly generated from MUSIC.

The estimation of the number of runoff days was carried out using the cumulative frequency distribution of runoff, using daily data aggregates. From the 6 minute flow calculations established by MUSIC, these are statistically aggregated and averaged for 24h blocks. For each day, MUSIC reports the estimated flows in each of the sub-catchments. For each sub-catchment the frequency of occurrence of flow days was determined and used as a proxy for runoff days. A frequency distribution curve is illustrated below (Figure 43).

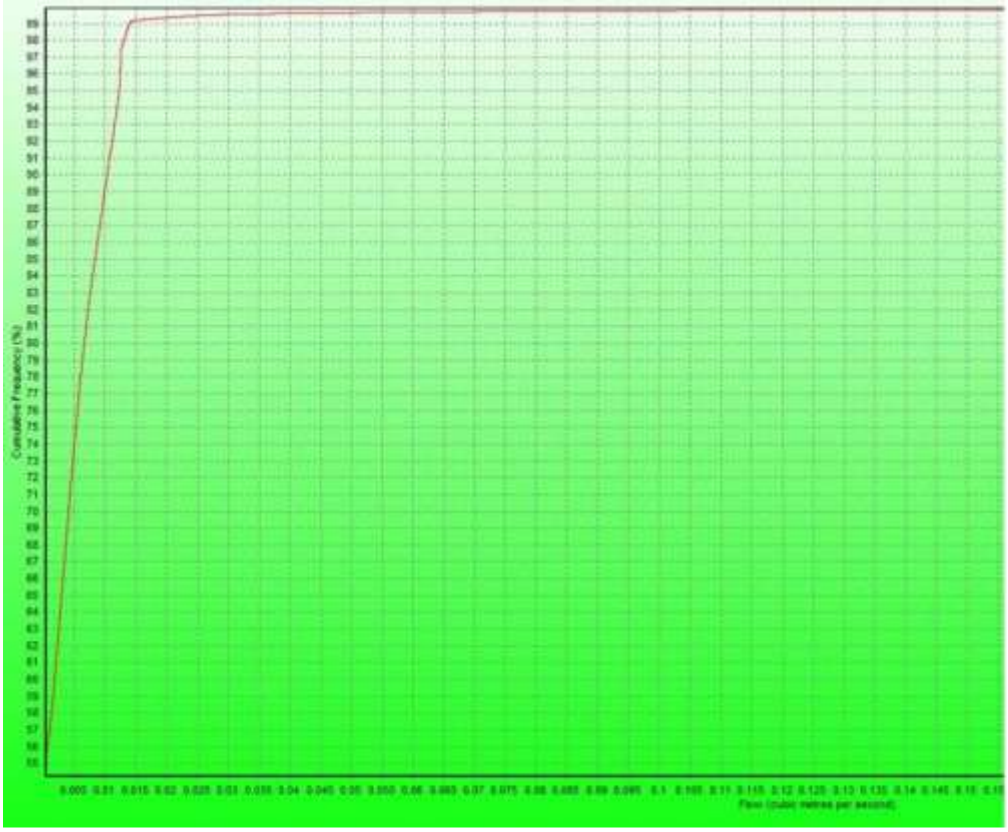

Figure 43 Runoff cumulative frequency distribution curve output from MUSIC

In the case above, over 55% of the time, there is no runoff. This means that runoff days are estimated to occur 45% of the time or an average of 164 days per year.

8.0 Protecting the Murrumbidgee River corridor gullies

8.1 Overview

The West Belconnen development site is largely a plateau isthmus bordered by the Murrumbidgee River and Ginninderra Creek. Ginninderra Creek passes through a major gorge prior to the confluence with the Murrumbidgee River. A series of steep ephemeral gorges drain a number of small catchments falling directly to the Murrumbidgee River. Several of the catchments draining to the Murrumbidgee River have experienced historic erosion as a result of past vegetation clearing and agricultural land use. Most gully lines will require stabilisation works and revegetation to safely convey increased runoff frequencies and volumes from urbanised catchments, other more or less intact gullies will require flow regulation for protection. The gully areas are also the areas largely protected as habitat for the threatened Pink-Tailed Worm Lizard.

Figure 44 **Ephemeral waterways within the West Belconnen development site**

An aspirational objective for the West Belconnen development is to achieve a *Green Star - Communities* “6 star” community rating. A key component to maximise the point scoring potential from the water management credits is achieving a 75% reduction in developed urban runoff volume for the protection of downstream waterways and preservation of the pre-development hydrological features for the catchments.

8.2 Flow attenuation requirements

The current urban drainage requirements are outlined in the *ACT Design Standards for Urban Infrastructure: 1 Stormwater*[24]. These guidelines indicate the West Belconnen site would require a minor drainage system capable of conveying the 5 year ARI developed flow and clearly planned and designated overland flow pathways. Conventional thinking about flood mitigation would also require the peak stormwater flows to be attenuated for the 5 year and 100 year ARI flow rates. This thinking emanates from the requirement to protect downstream infrastructure, properties and population.

For West Belconnen, it could be argued that 100 year ARI flood retardation is not necessary when there is no immediate downstream flood risk to other properties and when discharging to such a large system (Murrumbidgee River) or the lower end of a system (Ginninderra Creek). However, it will be necessary to provide a stable flow path from development areas to the Murrumbidgee River for flows up to the 1 in 100 year flow.

8.3 Flow requirements for protection of the ephemeral waterways

It is well known that urbanisation and conventional drainage will increase the frequency, rate and volume of stormwater flows to waterways. These more intense flows increase the shear stresses on the waterway bed and banks resulting in increased erosion and impacts on the geomorphology of the waterways. A number of the waterways in the area show signs of erosion from agricultural impacts including increased runoff and loss of vegetation and these will need to be repaired and revegetated while others are still in good condition.

The condition of the ephemeral waterways indicates that where flows are increased and vegetation is limited, this is likely to result in erosion of the bed and banks. The soils within the development area are fairly readily erodible and the gully lines are steep which can potentially lead to high velocities and shear stresses. In order to ensure that the waterways remain stable it is recommended that as a minimum:

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[24] Accessible at: http://www.tams.act.gov.au/city-services/Development_Approval_and_Applications/development_applications/design_standards_for_urban_infrastructure, accessed September 2014.

1) Ephemeral waterways are revegetated to provide resilience to increases in the frequency and duration of flows up to the 1 in 1 year ARI storm event

2) Flows for the 1 in 1 to 1 in 100 year ARI flows within the waterways are restricted to pre-development conditions to providing ongoing stable conditions.

Given the nature of the waterways, *i.e.* steep gully lines with sensitive habitat, it is considered that a retarding basin or equivalent will be required to regulate flows down the systems.

In the absence of such restriction of flows, it is likely that the waterways would be de-stabilised, resulting in the erosion from the waterways and deposition in the Murrumbidgee River of significant volumes of sediment. This would also in the long term impact upon the conservation area for the threatened Pink-Tailed Worm Lizard.

8.4 Option 1: Large stormwater harvesting scheme

8.4.1 General

A strategy to achieve a 75% reduction in developed urban runoff volume for the protection of downstream waterways is to deploy substantial urban stormwater harvesting. Modelling results (see Section 7.2) have suggested that harvesting would need to occur in virtually every sub-catchment in order to be able to harvest sufficient quantities, and this scheme is a part of the proposed ‘aspirational’ water management master plan for the development site (as per Section 3.0). This has led to the inclusion of a large number of stormwater attenuation and harvesting ponds and wetlands being proposed throughout the West Belconnen site. Without the large-scale stormwater harvesting, other methods (including gully ‘armouring’ or piping flows down the corridor) may be required; however these impede on the desire to limit the need for interventions within the corridor.

8.4.2 Addressing risks of relying on external users for water disposal

The stormwater harvesting strategy relies on finding willing external recipients of stormwater harvested from West Belconnen, *e.g.* the adjacent golf course. In the event that no external recipients can be found for the excess stormwater, it is possible to create an arrangement to collect water from the sub-catchments near the Murrumbidgee River corridor and divert flows to Ginninderra Creek. The justification for this approach is that Ginninderra Creek is not sensitive to the changes in hydrology that will result from discharging excess stormwater runoff from the development. Ginninderra Creek has a large catchment (32,000 ha) with persistent base flows. The hydrology of Ginninderra Creek has already been irreparably altered by a combination of extensive urban development, and the impoundment upstream with Lake Ginninderra. Further, the Riverview development is relatively small in comparison to the extent of urban development within the Ginninderra catchment (2.5%). Therefore, diverting excess water away from the ephemeral gullies that drain to the Murrumbidgee will protect the gully environments, and the excess will have no substantial impact on the condition of Ginninderra Creek.

The ‘aspirational’ scenario pipe, pump and tank network would only need minor reconfigurations to accommodate this change. It is also expected that capital costs would be similar.

A suitable discharge location along Ginninderra Creek needs to be identified. The discharge location must be assessed to determine if it can accommodate the discharge of excess treated stormwater. Minimising the discharge of excess treated stormwater to the Murrumbidgee can be mostly achieved through pump scheduling. Stormwater would be harvested by pumping preferentially from the Murrumbidgee catchments. Once those storages are drawn down, stormwater can be harvested from the Ginninderra catchments. This provides more storage for the Murrumbidgee catchments and minimises the volume and frequency of runoff to the gullies draining to the Murrumbidgee River. Thus most overflow of excess will occur in Ginninderra Creek, where the receiving environment will not be adversely impacted. The strategy for pump scheduling may involve:

1) Treated stormwater is pumped from the storages in the Murrumbidgee catchments to the header tanks for ‘third pipe’ distribution. When the Murrumbidgee storages have been drawn down and additional water is required to meet demands, water is then pumped from the Ginninderra catchments.

2) If the supply of water from the Murrumbidgee catchments exceeds demands (*i.e.* the header tank is full), excess flows will be diverted around the header tank and towards Ginninderra Creek.

3) This diversion to Ginninderra Creek can be made either with a dedicated gravity main pipe, or excess flows can be discharged to part of the stormwater drainage network. Discharging to the stormwater network would require the stormwater pipes to be upsized to a larger than practicable size and it is recommended that a dedicated gravity main be used.

The maximum flow rate for excess treated stormwater to be discharged to Ginninderra Creek is 80 L/s. This is based on the maximum flow rate for water pumped from the pond storages in the Murrumbidgee catchments to the header tank. This flow will require a 375 mm diameter pipe to drain for 1000 m by gravity to Ginninderra Creek.

Additional capital requirements may mean:

- Additional telemetry for valve control to trigger diversion of excess pumped water when treated storage tank is full and (nominally one unit)
- Overflow pipe (nominal 375mm diameter concrete pipe, grade 1%) from holding tank 1 (as per the WSUD drawing set) to gully immediately downstream of Basin 45 (approximately 1000 m)
- Outlet structure with energy dissipation/flow spreader to reduce scour (nominally provide for 10m^3 of boulders of 50th percentile diameters of 500 mm)
- Armoured flow path from outlet to creek as required (nominal 2 m wide, 10 m long rip rap channel).
- Make good and revegetation of disturbed areas (nominally 50m^2).

The total cost of this additional infrastructure would not be a major impost on top of the costs to provide the entire 'aspirational' stormwater harvesting scheme, though it has not been estimated formally.

8.5 Option 2: Small stormwater harvesting scheme + protection

The 'intermediary' case arrangement included:

- Elimination of the third pipe network to households (as described in the 'aspirational' scenario) and a reduced reliance on stormwater harvesting to enable smaller, decentralised harvesting and irrigation systems (primarily to manage the site water balance and control flows)
- Providing additional water capture and piping infrastructure and/or drainage line protection may be necessary to accommodate higher peak flows along the river and creek corridor than would otherwise be experienced under the 'aspirational' case (due to lesser stormwater harvesting), particularly those at the site extremities.

Regarding the scour and erosion control of the gullies, note:

- Given the limited ecological values, flat slope and proximity of the proposed WSUD (wetlands, ponds, *etc.*) measures to Ginninderra Creek (refer to the WSUD drawing set) it will be feasible to simply include stabilised and adequately designed waterways to drain the northern part of the site to Ginninderra Creek
- For the Murrumbidgee River interface, a more delicate approach could be taken. The proposed additional gully protection measures are shown as a sketch at Appendix f, including:
    - A proposed series of small size stormwater drainage pipe along the urban edge of the Murrumbidgee Corridor to transfer the small flows corresponding the discharge of the small frequent storm and extended attenuation volume, and by doing so divert water away from more sensitive and erosion prone gullies to more stable, less sensitive ones where erosion and scour protection can be reinforced
    - Co-locating as much as possible some additional stormwater drainage mains with a proposed (and only potential) sewer alignment largely following the urban side of the river corridor boundary. This would reduce construction cost and simplify the access and maintenance.

The details and cost estimates associated with these gully protection measures are still to be determined, and this needs to be considered in comparing the 'intermediary' option against the preliminary cost estimates for the other scenarios.

8.6 Option 3: No harvesting and piping flows from the plateau to the river

In the possible absence of a stormwater harvesting scheme, the intent of this option is to try and find ways of downsizing the stormwater attenuation basins by allowing larger flows than is commonly permissible to be discharged into the Murrumbidgee River, while maintaining the integrity of the gullies. Because of the steep slopes and high flows in question, it is not possible to consider conveying flows over land. Consequently, some significant stormwater drainage infrastructure is required by way of large stormwater pipes, chute pits in places and large energy dissipation devices by the Murrumbidgee River formed by armoured concrete impact basins.

AECOM and Brown have jointly investigated the preliminary sizing and costing of such infrastructure. The high level findings are for:

- Approximately 17 km of large diameter pipes

- Pipe sizes varying from 750 mm diameter to twin 1500 mm diameter pipes
- Three extra-large impact basins for energy dissipation of the larger catchments
- Six large impact basins for other catchments
- Challenging pipe hydraulic conditions with velocities potentially in excess of 8m/s unless mitigated with chute pits or purpose designed and built pipes.
- Challenging constructability issues and intricacy of the detailed design of the pipes to avoid impacting sensitive environmental values

The infrastructure cost may be in excess of an additional $12M for stormwater pipes and $600,000 for the impact basins, excluding any cost contingency associated with the construction premium for the difficult terrain and risks from regional flooding. More detailed examination of the infrastructure and possible costs can be developed at later stages; however these corridor protection measures, if required, will have costs that need to be considered when comparing estimates for the various water management cases presented in this study.

8.7 Recommendation

To provide effective protection of these waterways following development it is recommended that the following are satisfied:

1) Ephemeral waterways are revegetated to provide resilience to increases in the frequency and duration of flows up to the 1 in 1 year ARI storm event
2) Flows for the 1 in 1 to 1 in 100 year ARI flows within the waterways are restricted to pre-development conditions to providing ongoing stable conditions

Providing these protective measures will assist in the reestablishment of vegetated systems in the gullies that drain to the Murrumbidgee River. Vegetating these gullies will create an environment with the properties of resilience and adaptability, *i.e*. that is resilient to disturbance, and is able to recover after perturbation. When soil is covered by vegetation, its resistance to scour is considerably enhanced *i.e.* surfaces vegetated with grass may have an erosion threshold of up to 240 Nm^{-2}, much higher than the erosion threshold of bed materials such as stiff clays (22 $N\ m^{-2}$) (Blackham, 2006).

Achieving a 75% reduction in stormwater flow discharges from the site, as driven by the *Green Star – Communities* rating system, aids meeting these requirements and so provides protection to the vulnerable elements of the Murrumbidgee River. Both effective protection of the waterways and harvesting of 75% of urban runoff will require flood retardation basins on most catchments. The retarding basins will need to contain wetlands in their floor for water quality management of the harvested flows. The retarding basins allow for the interception of urban runoff and harvesting in a multi-functional way. The combined stormwater management system provides:

- A flow regulation system for discharges to the steep gullies draining the site
- A stormwater treatment point
- A stormwater harvesting point
- A landscape feature
- A flow regulation point for regulating the wetting regime of the pink-tailed legless lizard habitat areas.

Harvesting 75% of the urban stormwater runoff volume will mean most of the increase in frequent flow runoff volume (up to the 1 or 2 year ARI) will be intercepted by the harvesting system. However the retarding basin will need to control developed flows back to pre-developed conditions for the 1-2 year ARI flow and the 100 year ARI flow. Flow retardation will protect the gullies and the Pink-Tailed Worm Lizard habitat between the 1-100 year ARI flows and revegetation of the waterways and the harvesting system will control flows below the 1 year ARI. It is expected that stormwater harvesting will reduce the size of the retarding basins required by providing some control of the more frequent peak flow events. Such an approach can minimise drainage works in the steep river conservation area to provide effective conveyance of flows, protect receiving waters from the impacts of urbanisation, and achieve a high level of stormwater harvesting and use. Each of the retarding basins and stormwater treatment systems will be scaled appropriately to the corresponding catchment area.

A stormwater management and drainage strategy including retarding basins, wetlands and stormwater harvesting has the capacity to meet these requirements, minimise the costs and complexities of downstream infrastructure within the conservation zone and provide effective protection of the ephemeral waterways and Murrumbidgee River. As such, it was explored further as a component of the overall water management master planning.

9.0 Consultative refinement of the scenarios

The process of development of the integrated water management scenarios on this project was a continuous and collaborative approach which involved a large number of interactions and consultation with the Riverview, the ACT Government, other consultants and specialists represented on the project as well key stakeholders.

This section summarises some of the key infrastructure optimisation exercises that were carried out as well as the key consultation processes that occurred during the investigations

9.1 Consultation processes

A summary of the key consultations undertaken to advance the WSUD strategy is provided below:

Table 41 Key consultation processes on the Integrated Water Management strategy and infrastructure

Stakeholder	Consultation points and comments
Client group (Riverview and LDA)	Consultation and project status update reporting has been ongoing over the project duration, from September 2013 to present. This included presentations at the 'Big Ideas' (Oct 2013) and 'Planning and Design' (Nov 2013) forums, delivery of a principles and status update report in December 2013, and support at various other project meetings over the study course
ACT Government	Ongoing consultations with **Economic Development Directorate's** water infrastructure advisors. At these discussions the concerns over the economic feasibility of the 'aspirational' scenario stormwater harvesting scheme and who would operate it, in particular have been heard. To respond, this study has seen the development of three alternate possible water management arrangements, with differing environmental performance and cost. These can form the basis for further work or decision-making on the water management arrangement that might bring the greatest community benefit. The issue of an appropriate operator is still to be resolved. Ongoing consultations with **Territory and Municipal Services**, where concerns and needs in regard to asset maintenance and budgets were heard. The WSUD strategy has aimed to minimise the infrastructure requirements as far as practical yet the master plan still needs to respond to the water flow and quality requirements set in relevant codes and guidelines. A meeting was held with **ACT Health** in November 2013 and attendance at the November 2013 'Planning and Design' forum. ACT Health has an interest in ensuring that health risks from alternate water system proposals can be demonstrated to be adequately managed. A preliminary health and scheme risk assessment was undertaken, as at Section6.5, to inform the higher potential alternate water schemes; however ACT Health will have requirements to be met prior to any scheme being approved.
NSW Health and the Independent Pricing and Regulatory Tribunal (IPART)	NSW Health and IPART, as key water system regulators in NSW, were contacted to discuss the implications of a potential 'cross-border' stormwater harvesting scheme. The advice was that technically the NSW requirements (including attaining a Water Industry Competition Act licence) would apply for the NSW portion, but that the NSW and ACT regulators could come together and attempt to establish a 'single regulator' arrangement.
ACTEW Water	Participated in site inspections and at the Planning and Design' (Nov 2013) forum. ACTEW Water has requested to be kept informed on developments in regard to WSUD master planning at the site.
Other consultants and specialists	As necessary, consultations with other specialists have informed the WSUD master planning, particularly including: • Roberts Day – to ensure the WSUD measures were incorporated and responding to the overall master plan • McGregor Coxall – to discuss 'biostreet' concepts and landscape and water interactions • Brown – on sewer, water and trunk stormwater integration • Mr D. Shorthouse and Mr W. Osborne – the environmental consultants have provided environmental constraints advice and feedback as requested, particularly on river corridor management and wetlands/ponds locations • Prof. Tony Wong who was provided a presentation and is acting as a peer reviewer on the project.

9.2 Feedback and optimisation objectives

Through the various phases of consultation, the strategies and infrastructure solutions were subjected to substantial technical and strategic reviews, peer reviews and significant input from other consultants working on the West Belconnen project. Some of the most important ones are summarised below.

Table 42 Key feedback and optimisation objectives integrated in the WSUD/IWCM strategy

Strategy or infrastructure aspect	Input/feedback received	Resolution/comments
Stormwater harvesting	The ACT Government and the ICRC currently do not support stormwater harvesting on a water security basis; it must be economically sound given recent investment in the ACT's Water Security Projects	To date, stormwater harvesting has only been considered from a water resources, water security perspective in the ACT. On this project the proposed stormwater harvesting scheme and associated 'third pipe' network emanate from the need to mitigate the impact of urban stormwater excess on receiving waterways, while providing some added water security benefit
WSUD measures	The number of WSUD measures is too high and needs to be consolidated	The number of WSUD measures is primarily driven by the topography of the site. Wherever possible with reasonable regrading and earthworks, measures have been consolidated in a way to still meet flow and quality objectives
	Maintenance requirements and costs are a major concern	WSUD measures can be and will be designed for low maintenance regimes. It is impossible to eliminate the need for maintenance. It is difficult to protect waterways and water quality without WSUD measures. Alternative models for maintenance and maintenance funding may be explored as the community designs progress
	Dam embankments may be risky and reduced the amenity of the Murrumbidgee River corridor	The location of the WSUD measures was selected to minimise the height of the necessary embankments. The majority of the dam walls are less than 5m in height and none exceeds 11m. None of the dams are referrable to Australia New Zealand Committee on Large Dams (ANCOLD) for safety assessment thanks to their compact design.
	Basins cannot be located within 20m of Pink-Tailed Worm Lizard habitat in the Murrumbidgee River corridor without exception, and including the dam wall tails	All basins were verified and a small number relocated during design iterations.
	Proposed B11 Wetland impacts exceptional trees no. 57 and 58	B11 Wetland design modified and split as B11 and B11A wetlands
Stormwater harvesting scheme infrastructure	Proposed location of the stormwater treatment plant near the entry to the West Belconnen estate is not desirable. Treatment plant to be relocated to the landfill site.	Initial location for the stormwater treatment plant was driven by elevation and attempt to supply the non-potable network by gravity only. Stormwater treatment plant relocated to the landfill site as suggested. Supply of water will be by gravity for most of the urban areas except for the south east corner which will require a booster pump. The suitability of the landfill to accommodate such a structure

Strategy or infrastructure aspect	**Input/feedback received**	**Resolution/comments**
		needs to be assessed as part of future work
	Proposed location of harvesting tanks in multiple locations in the urban areas should be replaced by tank farms at the landfill site	Tank farms have been adopted for a total capacity of 8ML of raw stormwater and 8ML of treated stormwater.
	Pumping costs and other operating costs for the stormwater harvesting scheme will be excessive	The stormwater harvesting scheme infrastructure is conceptual only at this stage of the project. The purpose was to demonstrate the technical feasibility. Optimisation of the infrastructure and pumping regime would require a more sophisticated network model which will be done in subsequent stages of the project.
External irrigation demands	Estimated external demands for stormwater supply are optimistic and unverified	The potential external demands identified are located within a 3km radius of the site. Demands are based on estimates of irrigated or potentially areas for irrigation. The next stage of these initiatives would be to engage with the various potential users and carry out or more detailed feasibility investigation including a willingness to pay evaluation. The alternative to exporting water off the site could be to discharge the excess unused stormwater excess via a dedicated pipe into the more stable Ginninderra Creek to the north (see Section 8.4.2).
Environmental outcomes	Please quantify and address the potential impact of extreme storms on the Murrumbidgee River corridor gullies	A Probable Maximum Flood analysis was carried out and results are provided in Section 7.1.4
Strategies	The project needs to achieve better environmental outcomes than the ‘base case’ strategy, but the costs associated with the ‘aspirational’ strategy may make it unachievable. Develop an alternate strategy that would allow an investigation into the potential trade-off between environmental performance and cost.	The stormwater harvesting scheme represent a significant infrastructure cost to the project. It is important that benefits be also considered in the evaluation of feasibility and cost-benefit analysis. These benefits relate to the liveability, resilience and comfort of the future community. An ‘intermediary’ strategy was developed to further explore this issue, and to compare against the ‘base’ and ‘aspirational’ cases.

10.0 Sensitivity analysis

10.1 Climate change impacts and drought

10.1.1 Climate change projections for the ACT region

There have been numerous studies assessing the potential impacts of a changing climate, including perhaps the most authoritative with regard to Australia by Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (2007). CSIRO (2010) has reviewed these and determined that the most likely future climate in the Canberra region is one that is hotter with little rainfall changes. Projections are for annual air temperature to be between 1.8°C and 2.9°C warmer compared to current values; summer temperature between 1.8°C and 3.1°C warmer; and mean rainfall changes between -4.6% and + 4.4% by 2050. The suggested worst case scenario for a likely future climate in the Canberra region is hotter with drier conditions. This scenario corresponds to annual air temperature between 1.9°C and 2.7°C warmer compared to current values; summer temperature between 2°C and 3.1°C warmer; and mean rainfall decrease between -13% and -5.2% by 2050.

10.1.2 Drought resilience

Regardless of the potential or likely impact of climate change, Australia and the ACT in particular are known for the high variability in the rainfall. While the last few years have seen fairly average precipitation, Canberra has experienced a severe and prolonged drought in the recent past.

Stormwater harvesting schemes rely on rainfall for the supply of water. In dry periods, the stormwater harvesting scheme will not be able to meet the demands. The specific back-up source is potable water, but during a prolonged drought it is quite likely that the surface water dams that make up Canberra water supply system would be under supply pressure as well.

Importantly, West Belconnen has the possibility to source water from the Lower Molonglo Water Quality Control Centre in the future. Treated effluent is a high reliability resource. Even during periods of drought when garden irrigation, public open space irrigation, commercial and industrial uses may be restricted, basic human water needs for showering, toilet flushing, etc. will continue to generate flows into the LMWQCC.

While this report does not identify treated recycled water as a priority in the short term, or based on the sustainability and environmental objectives, it is conceivable that treated effluent could be considered at a later stage.

10.2 Sensitivity of the stormwater harvesting scheme reliability

Understanding the reliability of the stormwater harvesting scheme to changes to key modelling assumptions is important. A number of sensitivity analyses were carried in order to under the potential impact of a number of factors including:

- Rainfall data
- Imperviousness fraction
- Climate change impact on historical rainfall data.

Using the same simplified model that was used to establish the reliability and high level infrastructure sizing for the ‘aspirational’ centralised stormwater harvesting scheme, modified models were run as outlined below.

10.2.1 Rainfall data

Section 4.4 details the comparison between the reference meteorological station at Canberra Airport and some of the rainfall gauges that are located in closer proximity to the site. A substantial difference in rainfall was observed with the potential for annual rainfall to exceed 700mm (compared to 655mm at the reference station).

The stormwater harvesting scheme model was tested using a 725mm annual precipitation which corresponds to indications of partial recordings in the vicinity of the project.

Finding: the stormwater volume available for harvesting may vary by up to +11%.

10.2.2 Inaccuracy in imperviousness fraction

Hydrological models are particularly sensitive to imperviousness estimates. The imperviousness estimate for the West Belconnen project was 65% overall. This is lower than most typical urban development projects in the ACT which tend to have imperviousness between 70% and 75%. With higher imperviousness would be associated increased flows, while lower imperviousness could reduce the reliability of the stormwater harvesting scheme.

In this sensitivity analysis, the impervious fraction in the model was modified to obtain a similar reduction in stormwater harvesting as can be expected from climate change.

Finding: the error in imperviousness fraction that results in the same changes in available runoff is less than 5%.

10.2.3 Climate change impact

As presented above, climate change projections for the Canberra region indicate a possible reduction in annual rainfall by -4% by 2050.

The water balance modelling was tested with a -4% reduction in annual precipitation (629mm/year compared to 655mm/year average for the reference period).

Finding: the stormwater volume available for harvesting may vary by up to -4.1%.

10.2.4 Conclusion

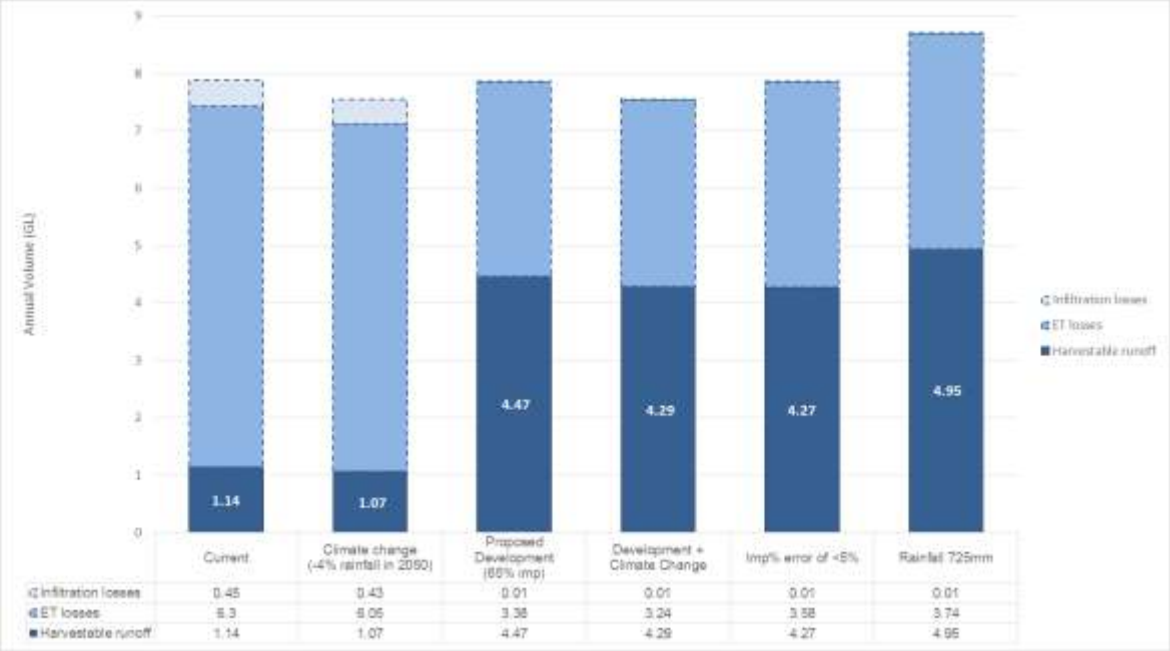
The stormwater harvesting modelling that has been carried out represents a reasonable, conservative estimate of the likely reliability of the proposed stormwater harvesting scheme in West Belconnen

The tests performed reveal that the reliability of the system will be sensitive to errors and inaccuracies in rainfall data, the impact of climate change or impervious fraction.

The most important parameter is the rainfall dataset. If the reference rainfall data set (Canberra Airport 1968-1977) is the most appropriate for the purpose of comparing the proposed infrastructure with other projects in the ACT, and for the purpose of reporting against the *Green Star - Communities* framework, it may underestimate the reliability of the scheme.

The impact of climate change on annual rainfall is limited. Importantly, the predicted impact of climate change is comparable in magnitude to a small inaccuracy in imperviousness. This means that a couple of percentage points in imperviousness would have the same impact on the validity of the outcomes presented in this report. Equally this means that the potential impact of climate change could be either: (i) exacerbated or (ii) compensated by even small changes in imperviousness as the project progresses.

Figure 45 summarises the total annual water balance for the project and shows the impacts of climate change, changes to imperviousness or rainfall data.



	Current	Climate change (-4% rainfall in 2050)	Proposed Development (66% imp)	Development + Climate Change	Imp% error of <5%	Rainfall 725mm
Infiltration losses	0.45	0.43	0.01	0.01	0.01	0.01
ET losses	6.3	6.06	3.38	3.24	3.58	3.74
■ Harvestable runoff	1.14	1.07	4.47	4.29	4.27	4.95

Figure 45 Annual water balance sensitivity analysis

PART THREE

Progressing and Evaluating the Master Plan

11.0 Discussion

11.1 Key outcome

Upon reviewing the water management scenarios in this report, note that each arrangement meets the water quality and flow management requirements of the future development particularly as outlined in the ACT's WSUD Code, with various levels of environmental performance beyond that baseline and with different associated costs. Investigations to determine the optimal WSUD solution are ongoing and from here will be informed by a 'triple bottom line' assessment of community and stakeholder environmental, social and financial impacts and benefits, as described below.

11.2 *Green Star – Communities* vs. the ACT WSUD Code

While some have offered that the ACT WSUD Code may be overly ambitious (as noticed during recent work of the Technical Panel on the review of the ACT WSUD Code, to which one of the report authors has participated) and may not to lead to optimum outcomes for the Canberra community, it has not rated particularly well in terms of achieving against the water-related sustainability objectives of the *Green Star – Communities* tool for this case-study (see the difference in the environmental scorecards of the 'base' and 'aspirational' cases respectively). The primary reason for this is the strong focus from the ACT WSUD Code on pollutant load reduction but the relative absence of requirements with respect to stormwater quantity management and mitigation of impact of urban development on the hydrological regimes of urban waterways. It is worth noting that at the time the ACT WSUD Code was prepared, this issue was not as well understood and characterised as it is today.

The *Green Star – Communities* tool can be considered as a good tool to drive integrated approaches to water management. The structure of the criteria means that it is not possible to achieve on certain criteria without paying attention to the others. In other words, to achieve an outcome that would rate well under the Green Star – Communities scheme, it is necessary to consider all aspects of a sustainable community jointly. A noticeable outcome of this in the example of the West Belconnen 'aspirational' strategy is that in order to achieve the flow volume reduction target of 75% reduction, a number of initiatives including centralised stormwater harvesting, non-potable water network (third pipe), irrigation of public open space and urban food production.

Importantly however, from a strict water quality context, the ACT WSUD Code regional targets have been tested and it can be concluded that they correspond to leading practice in Australia.

11.3 The key challenge: urban stormwater excess

After experiencing a difficult period of prolonged drought general perceptions are that one of the problems that have to be addressed as part of a project like the West Belconnen development is the security of water supply and providing resilience and diversification of water sources.

This is certainly relevant across Australia, as we need to better plan our suburbs, communities and society as a whole to be more sensitive to water management issues.

At West Belconnen however, because of the topography and environmental assets that need protection, the issue is vastly different. The key problem is not strictly of water security and drought management, but it is rather an issue of managing the urban stormwater excess that is generated by the impervious surfaces.

Under current conditions, from a total precipitation volume of 7.9 GL that falls across the entire site, the vast majority is either infiltrated, evaporated or evapotranspired by the vegetation (6.9 GL). The stormwater runoff represents 1.1 GL or approximately 15% of the total available precipitation.

Associated with the proposed development, is a vast increase in impervious areas associated with roofs, car parks, roads, footpaths, *etc*. The estimated post-development situation is for 64% of the site to be impervious. The impact on surface runoff is very significant. From the 7.9 GL of precipitation across the site, the stormwater runoff was estimated at 4.5 GL which represents 57% of the volume. This corresponds to an increase of +292%. It is interesting to note that the total annual household water demand for the West Belconnen community ranges from 0.9-1.4 GL depending upon the demand assumptions. The public open space irrigation was estimated to range between 0.8 -1.1 GL.

This study has outlined the range of potential issues and highlights potential mitigation strategies using integrated water cycle management principles and WSUD.

11.4 Stormwater harvesting: an environmental impact mitigation strategy

There are very few non-potable supply schemes in the ACT. The Canberra Inner North Effluent reuse scheme delivers treated effluent for irrigation reuse purposes to institutional and sportsgrounds. The Canberra Integrated Waterways stormwater harvesting scheme has been constructed for many months now, but license agreements are preventing the actual delivery of any water. There are a few small scale stormwater harvesting schemes for sports facilities and parks in the immediate vicinity of some ponds and wetlands.

ACTEW Water and the ACT Government have recently completed a $400m+ investment in the Enlarged Cotter Dam project which was designed to safeguard the long term security of Canberra's water supply. Subsequently the ICRC has adopted a financially conservative position by excluding government investment for the time-being in any non-potable water supply scheme on water security grounds, as the recent investments should eliminate the need for any further investment in water security the short term. Cases can be made on economic, or triple-bottom-line, bases.

At West Belconnen, the proposed stormwater harvesting scheme is not a response to perceived risks of water supply. Had water security had been the primary driver it is possible that a water recycling scheme from the LMWQCC would have been preferred given the extreme supply reliability of the resource.

It is important for all stakeholders and the ACT Government to understand the rationale underpinning the proposed stormwater harvesting scheme (particularly for the 'aspirational' case). At West Belconnen, the stormwater harvesting is an environmental impact mitigation strategy. Its key drivers are summarised below:

- Associated with the proposed urban development, is a modification of the natural hydrology of the site, including creation of a large volume of excess stormwater runoff
- Unmanaged, these excess urban stormwater flows represent an estimated increase of +292% of flows down the escarpments of the Murrumbidgee River corridor and Ginninderra Creek
- To protect the Murrumbidgee River corridor in line with the sustainability vision and principles, there is a need to manage this increased flow volume
- While peak flows can be mitigated using common WSUD measures, these measures do not reduce flow volumes sufficiently to achieve the necessary reduction at West Belconnen
- Stormwater harvesting is required in order to reduce the urban excess flows, and to try and mimic pre-development hydrological regimes
- Supplying stormwater to as large demands as possible, including household non-potable demands (toilet flushing, laundry, garden irrigation) can mitigate the potential impact on the environment and limit infrastructure interventions being required in or down the Murrumbidgee River corridor

While offering increased resilience and diversity of water supply sources, and a reduced potable water demand on Canberra's water supply system, the proposed non potable water supply scheme at West Belconnen is not a response to water supply security concerns. Upon investigating potential ways of mitigating the environmental impact of the development, stormwater harvesting revealed itself to be a strong response to tackling the urban stormwater excess runoff problem.

There will be further work required to develop this concept into a fully functional scheme, including technical designs, as well as better understanding potential governance and business models. As the proposed scheme for West Belconnen is progressed further it will be important for stakeholders to appreciate its fundamental objective: mitigating the potential impact of increased flows on the ephemeral gullies of the Murrumbidgee River corridor.

11.5 Integrated water management: a governance challenge

The significant challenge relating to the proposed integrated water management approach lies in resolving a business model and governance arrangement that would be acceptable to ACT Government stakeholders such as ACT Health, the ICRC, ACTEW Water, and TaMS, as well as to the community.

Consequently, an operator and business model for a stormwater harvesting system needs to be tested and progressed. Some of the key issues include:

- Business model: private operator, not-for-profit entity, community owned structure, ACT Government run scheme
- Pricing levels and possible operational margins
- Long term financial viability of the scheme
- Contingency in case of business model failure

As the concept for an integrated water management approach at West Belconnen is further progressed and debated, it will be important to emphasize the nature of the challenge: establishing the most appropriate government and business model for the non-potable water management aspects.

12.0 Evaluation of the performance over time

It will be important to measure the water quality and flow management performance at the West Belconnen site over time, to establish the success of the WSUD strategy and to provide valuable information and lessons for future work. A monitoring and evaluation plan has been prepared for consideration by the project stakeholders, and is at Appendix g.

13.0 Next steps

The integrated water cycle management strategy, WSUD strategy and infrastructure outlined in this report form the first step in developing a new model of ‘low impact’ urbanism at West Belconnen. From here, there are several areas for further investigation and development that require consideration and implementation, as shown at Figure 46 and elaborated on below.

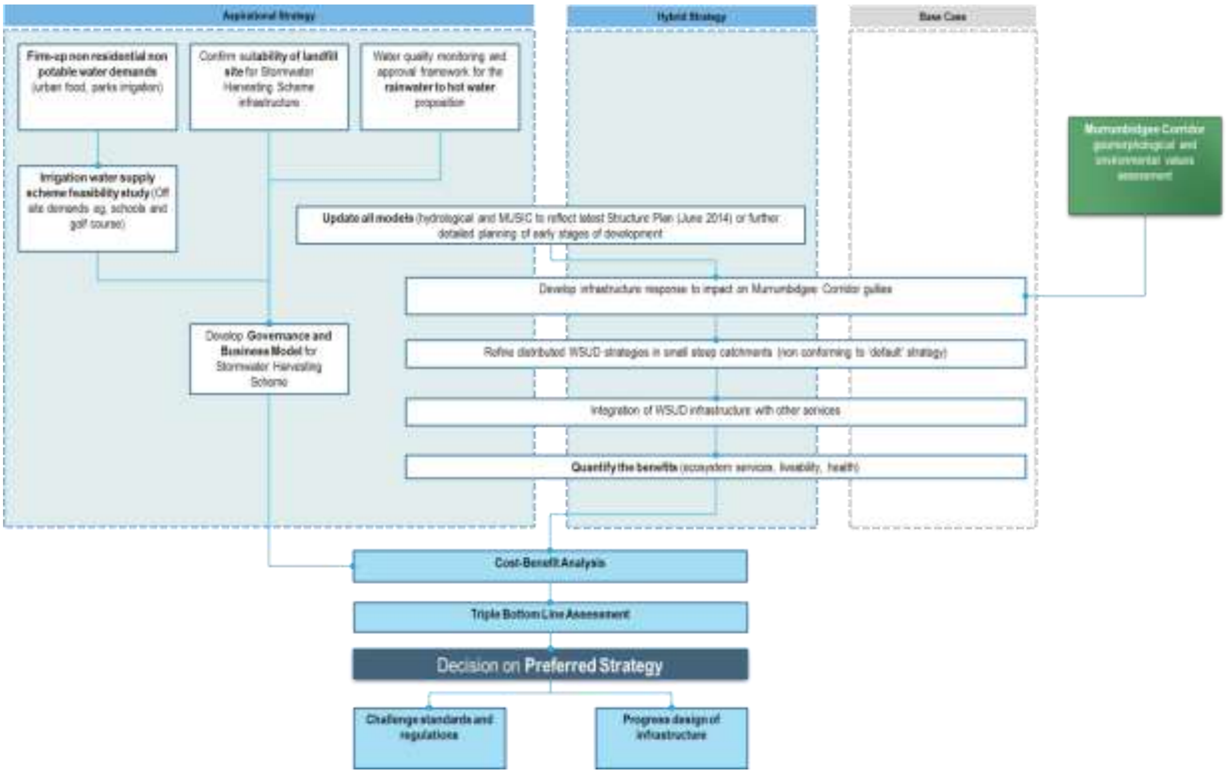


Figure 46 **‘Next steps’ framework**

13.1 Quantifying the benefits

A detailed benefit-cost assessment can be useful to establish the preferred arrangements for the water management regime and, in particular (if it is part of the preferred arrangement) understanding the possible business/governance arrangements of a stormwater harvesting scheme (especially considering the inter-jurisdictional context) is necessary. Though the ‘aspirational’ case establishment costs are much greater and have higher recurrent operational and maintenance costs, it remains to be further tested whether and to what extent these may be offset through improved environmental outcomes, avoided infrastructure and/or the sale of the stormwater for domestic and public space uses, as well as to gauge the community’s willingness to pay for the resource. Triple-bottom-line assessments help to construct a balanced decision making process by considering the social, environmental and financial aspects of proposals. Ultimately, a triple bottom line (TBL) assessment should be undertaken on all scenarios to determine where on the spectrum of options between the identified ‘base’ and ‘aspirational’ cases the preferred solution may be.

At West Belconnen, the financial performance assessment will be further improved by undertaking a cost-benefit analysis for the various water management strategies. This means that the varying level of services from the range of strategies will be taken into account. Some of the initiatives such as stormwater harvesting for irrigation of the public open space and parks would deliver a greater range of ecosystem services than a business as usual scenario. By helping to reduce urban heat island effects and supporting an increased level of active lifestyles thanks to improved quality the public realm, these initiatives will generate highly valuable benefits to the West Belconnen community over the long term.

The financial evaluation of ecosystem services is a subject of extensive research around the globe as the costs of poor urban design and planning are proving costly to manage in many urban areas. There are a number of ecosystem services that could be considered including:

- Health and social benefits of higher quality public open space
- Health, social and productivity benefits of reduced impacts of heatwaves
- Health and social benefits of reduced urban heat island effect
- Economic and social benefits of cooler 'micro-climate' areas.

13.2 Governance and business model for the non-potable water supply network

The management of any alternative water supply scheme will need to be done in accordance with *Australian Guidelines for Water Recycling* including developing a water quality monitoring, validation and verification plan, and by working with relevant local utilities and regulators. There are some possibilities for establishing a non-potable water supply entity, each with their own challenges. It is necessary to evaluate the potential business/governance models and the conditions around them (with reference to relevant Acts and Regulations, codes, etc.) that would be necessary to sustainably manage the proposed stormwater harvesting scheme. Four scenarios could be tested:

- ACTEW Water as the scheme owner and operator
- Territory and Municipal Services as the scheme owner and operator
- A private investor (e.g. Flow Systems) setting up as a utility in the ACT
- A community operated (perhaps not-for-profit) scheme.

13.3 Water quality monitoring and approval framework for the rainwater to hot water system

Importantly the potential role of alternative water sources requires further testing. Presently there is no obvious owner and operator of a stormwater harvesting scheme, and no precedent in the ACT of providing such a scheme for domestic water uses. As part of the 'whole water system and community' benefit-cost assessment described above, it would be necessary to determine the viability and models for establishing a stormwater harvesting, treatment and delivery entity. The identification of the owner/operator is currently a major challenge in the ACT regulatory framework. The Canberra Inner North non potable network is a recent example of the potential challenges to be addressed. Beyond the regulatory challenges, the business case needs to be progressed further as well. A preliminary analysis as part of this study has suggested that the harvested stormwater may need to be charged at a rate significantly less than is currently placed on potable water to avoid placing additional costs on householders.

Additionally, the proposal to use rainwater for hot water and to provide stormwater via a 'third pipe' into households will require the development of the appropriate water quality monitoring and control mechanisms and approval by relevant health authorities in the ACT and NSW. The preliminary work carried out identifies a possible treatment train that would satisfy these requirements and would be in accordance with *Australian Guidelines for Water Recycling* including a water quality monitoring, validation and verification plan.

13.4 Progressing to a preferred arrangement and detailed design

A continued focus on consultation with relevant organisations and bodies will be required to further develop the water sensitive urban design components of the master plan. Liaison with the asset management entities (most likely Territory and Municipal Services and/or ACTEW Water in ACT and Yass Valley Shire Council in NSW or a private sector water utility) that could inherit and maintain the stormwater management and WSUD infrastructure is required to establish asset design and acceptance criteria. Additionally, the ongoing funding for maintenance and operation of the WSUD measures including ponds, wetlands, bioretention systems and the stormwater harvesting infrastructure will be critical to the ongoing performance of the proposed treatment train. Failure to undertake the adequate maintenance of the assets could result in sub-optimal performance and outcomes over time. It will be important to explore how to ensure the necessary regime of maintenance by the key asset management entities can be made feasible, as well as what roles others (*e.g.* an environment/conservation trust, the local catchment group, or a dedicated not-for-profit community group) may play

13.5 Testing the suitability of the landfill site and technical feasibility of the stormwater storage and treatment works

The former landfill site was identified as a potential location for the tank farms and potential stormwater treatment plant. The decision was based on technical feasibility and urban design outcomes grounds. The landfill site will be the subject of a dedicated master planning exercise which will include a number of critical items such as timing and staging and a geotechnical assessment to the site conditions and any requirement remediation work.

The geotechnical suitability of the site needs to be confirmed for the purpose of accommodating the locally heavy load and how geotechnical improvements might support such a proposal, if required.

13.6 Update the water management models as structure plan evolves

The overall model developed to test stormwater quality, harvesting and flow management is based on a structure plan that was current at February 2014. An updated structure plan has been developed since. The strategic findings and figures reported in this document are still relevant for the purpose of land planning and strategic infrastructure planning. It will be important to revise the models prior to progressing to the next phase of water sensitive urban design.

In particular it will be important to update:

- Land use planning and density estimates
- Degree of imperviousness in each catchment
- Hydrological model and peak flow estimates
- Block yields and water balance model
- Provisions for WSUD measures and associated water quality improvement
- Overall flow attenuation and flow regime of the gullies.

13.7 Firm up the non-residential water demands including urban food production, irrigation and external demands

The non-potable water demand corresponding to the residential areas of West Belconnen form an important part to the ‘aspirational’ scenario for a centralised non-potable network. But this demand alone is insufficient to reduce the urban excess runoff volume to levels that would protect the integrity of the Murrumbidgee Corridor gullies or to demonstrate the necessary level of performance for a 6 stars green star community rating.

As part of the proposed water management strategy, this report identifies a number of additional non-residential demands that contribute significantly to improving the overall water management performance of the project. The demands identified include:

- Urban food production (within the site)
- Irrigation of public open space and parklands
- Selling non potable water to beneficial end users (off site), *e.g.* golf course and schools.

As part of this investigation, reasonable estimates were developed for the likely volume and seasonality of demands, in collaboration with the landscape architect and urban planners.

Refining and firming up these demands will be important to estimating the ultimate performance of the proposed ‘aspirational’ scenario. There are a number of parameters that will influence the feasibility and demands for non-potable water including:

- Distribution requirements (storage, flow rate, variability of supply)
- Water quality (salinity, turbidity, average water quality and any peaks)
- License conditions (pay per use, annual fees, price levels)

- Conditions of contract (reliability of supply).

As planning for such land uses progresses, it will be necessary to verify and refine the assumptions and test the impacts of any changes on the water system design parameters.

13.8 Refine distributed WSUD strategies in difficult catchments

The water quality management outcomes are not spread evenly across the site. Modelling suggests that a small number (4) of sub-catchments near the river corridor for which the topography or proposed land use pose particular challenges may have runoff water of poorer quality than other parts of the site. The expected total treatment train in these sub-catchments will require additional streetscape rain garden and bioretention systems in order to further improve the water quality. It is not yet possible to develop such ‘sub-catchment specific’ treatment trains as the urban design and planning has not progressed enough. This needs attention as the urban design and planning progresses.

13.9 Detailed integration of stormwater and WSUD planning with civil services and infrastructure

Integrating with the civil infrastructure planning and design is necessary, including integration of:

- Non-potable and potable infrastructure and reticulation networks
- Inlet and outlet structures to the basins, including locations of treatment of the points of discharge from basins
- Earthworks modelling and treatment of the embankments for the ponds, wetlands, *etc*.

13.10 Murrumbidgee River corridor drainage lines

Preliminary geomorphological studies of the corridor were undertaken to inform the discussion on some of the protection measures, but more rigorous investigations are required. Establishing the vulnerable and sensitive components of the corridor, and further determining the ability or need to place infrastructure in the corridor, may well provide some of the incentive as to which WSUD may best be adopted for the site. It is recommended to undertake a detailed geomorphic and ecologic investigation of the West Belconnen Murrumbidgee River corridor. This detailed study should form the basis of a Murrumbidgee River corridor management plan.

Glossary of Terms and Acronyms

ACT	Australian Capital Territory
ACTPLA	ACT Planning & Land Authority
AGO	Australian Greenhouse Office
AGWR	*Australian Guidelines for Water Recycling*
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	Average Recurrence Interval
ASCE	American Society for Civil Engineers
ASR	Aquifer Storage and Recovery
ASTM	American Society for Testing and Materials
BAU	‘Business as usual’
BOD	Biochemical Oxygen Demand
cfu	Colony-forming Unit
Ck	Creek
Cl_2	Chlorine
d	Day
DA	Development Application
DALY	Disability Adjusted Life Years
DEWS	Department of Energy and Water Supply (Queensland)
E. coli	*Escherichia coli*
ECON	Economic Prosperity
ENV	Environment
EPA	Environment Protection Agency (Victoria)
ET_C	Specific crop evapotranspiration
ET_0	Reference Evapotranspiration
FAO	Food and Agriculture Organisation of the United Nations
F-RNA	Fluoro-Ribonucleic Acid
GBCA	Green Building Council of Australia
GFA	Gross Floor Area
gha	Global Hectares
GOV	Governance
ha	Hectare
ICRC	Independent Competition and Regulatory Commission
INN	Innovation
IPART	Independent Pricing and Regulatory Tribunal
ISO	International Organisation for Standardisation
IWCM	Integrated Water Cycle Management

K_C	Crop coefficient
kg	Kilogram
kL	Kilolitre
km	Kilometre
km/h	Kilometres per hour
LIV	Liveability
LMWQCC	Lower Molonglo Water Quality Control Centre
m	Metres
m^2	Metres squared
ML	Megalitre
mg	Milligram
mL	Millilitre
mm	Millimetre
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NSW	New South Wales
NTU	Nephelometric Turbidity Unit
org	Organisms
OSD	On-site Detention
p.a.	*Per annum*
POS	Public Open Space
PTWL	Pink-Tailed Worm Lizard
PUB	Public Utility Board (Singapore)
Qld	Queensland
SRI	Solar Reflective Index
SS	Suspended Solids
TaMS	Territory and Municipal Services (ACT)
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
UK	United Kingdom
US	United States
UV	Ultraviolet (radiation)
Vic	Victoria
WICA	Water Industry Competition Act 2006
WSUD	Water Sensitive Urban Design
WSUD drawing set	Drawing set accompanying this report: *Ref. 60308190-DRG (AECOM Sep. 2014)*
y	Year

References

Australian Capital Territory (ACT) Government, 2004, *Think water, Act water*, Canberra.

Australian Capital Territory (ACT) Government, 2007, *Think water, Act water - Strategy for sustainable water resource management in the ACT: 2005-2006 Progress Report*, Canberra.

Australian Capital Territory (ACT) Government, 2004, *Grey water use – Guidelines for residential properties in Canberra*, Canberra.

Australian Capital Territory Planning & Land Authority (ACTPLA), 1997, *ACT Environment and Health – Wastewater Reuse Guidelines*, Canberra.

Australian Capital Territory Planning & Land Authority (ACTPLA), 2009, *Waterways - Water Sensitive Urban Design - General Code*, Canberra.

Australian Capital Territory Planning and Land Authority (ACTPLA, 2010), *Rainwater tanks - Guidelines for residential properties in Canberra*, Canberra.

ACTEW Water 2011, *North Canberra Effluent Reuse Treatment Scheme*, available at: <http://www.actew.com.au/Water%20and%20Sewerage%20Systems/ACT%20Sewerage%20System/Recycled%20Water/North%20Canberra%20Effluent%20Reuse%20Treatment%20Scheme.aspx>, accessed 21 January 2014.

Allen G, Pereira L, Raes D, Smith M, 1998, *Crop evapotranspiration – Guidelines for computing crop water requirements – FAO Irrigation and drainage paper 56*, Chapter 2 – FAO Penman-Monteith equation, http://www.fao.org/docrep/x0490e/x0490e06.htm#chapter_2_fao_penman_monteith_equation, accessed 30 January 2014.

Bewsher, D, 1993, 'On-site stormwater detention systems in NSW', proceedings of *the 33rd Annual Conference of Flood Mitigation Authorities of NSW*, Taree, NSW, 25-28 May.

Blackham, D, 2006, *The relationship between flow and stream channel vegetation*. PhD Thesis, University of Melbourne.

Bureau of Meteorology and Commonwealth Scientific and Industrial research Organisation (BoM & CSIRO), 2007, Climate Change in Australia: Technical Report, Canberra.

Brown, R, Keath, N, Wong, T, 2009, 'Urban water management in cities: historical, current and future regimes'. *Science and Technology,* **59**(5):847-855.

Brown Consulting, 2014, *West Belconnen – Sewer and Water Concept Plan Report*. Report for Riverview Group, 24 June 2014.

Cardno Willing, 2002, *Study on the Combined Effects of OSD and Rainwater Tanks on the Upper Parramatta River Catchment at Varying Sub-Catchment Scales*. Report prepared for the Upper Parramatta River Catchment Trust, October 2002.

Chief Minister and Treasury Directorate (n.d.), *Sustainability Policy.* Available at: http://www.cmd.act.gov.au/policystrategic/sustainability, accessed 8 December 2013.

Chief Minister and Treasury Directorate (2013), *Climate Change Vulnerability Assessment Framework for Infrastructure.* Available at: http://www.cmd.act.gov.au/policystrategic/sustainability, accessed 8 December 2013.

Chief Minister and Treasury Directorate (n.d.), *Triple Bottom Line Assessment Framework.* Available at: http://www.cmd.act.gov.au/policystrategic/sustainability, accessed 8 December 2013.

Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2010, *Climate Futures for Canberra*, a consultancy report for AECOM, June 2010.

Deere, D., Billington, K., O'Toole, M and Sinclair, M. 2012, *Supply of roof-harvested rainwater to residential hot water services – microbial risk assessment*, report to Melbourne Water by Water Quality Research Australia, Melbourne, Australia.

Department of Environment and Conservation, 2004, *Environmental Guidelines: Use of Effluent by Irrigation Requirements*, NSW Government, Sydney.

Department of Water and Energy, 2008, *The Interim NSW Guidelines for Management of Private Recycled Water Schemes*, NSW Government, Sydney.

Elton Consulting, 2013, *Towards a Vision for West Belconnen. Outcomes Report on the Community and Stakeholder Vision Workshop and the Planning and Design Forum (11 - 14 November 2013).* Report for the Riverview Group, 20 December 2013.

Engineers Australia, 2006, *Australian Runoff Quality – A guide to Water Sensitive Urban Design*, Canberra.

Environment ACT, 1999, *ACT Wastewater Reuse for Irrigation,* Environment Protection Policy, Canberra.

Environmental Protection Authority (EPA) Victoria, 2003, *Guidelines for Environmental Management – Use of reclaimed Water*, EPA Victoria, Southbank, Melbourne.

Garnaut, R, 2008, *The Garnaut Climate Change Review,* First edition, Cambridge University Press, Victoria, Australia.

Green Building Council of Australia (2012), *Green Star – Communities PILOT Manual*, GBCA, Brisbane.

Independent Competition and Regulatory Commission (ICRC), 2012, *Final report - Secondary water use in the ACT.* Available at: http://www.icrc.act.gov.au/wp-content/uploads/2013/02/Report_6_of_2012_July_2012.pdf, accessed 10 December 2013.

McGregor Coxall, 2014, *West Belconnen Landscape and Open Space Strategy*. Report for Riverview Group, 19 June 2014.

National Water Commission (NWC), 2007, *Institutional and Regulatory Models for Integrated Urban Water Cycle Management – Issues and Scoping Paper*, Australian Government, Barton.

National Health and Medical Research Council (NHMRC), 2006, *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)*, Canberra, Australia.

National Health and Medical Research Council (NHMRC), 2011, *Australian Drinking Water Guidelines*, Canberra, Australia.

New South Wales Department of Environment, Climate Change and Water (NSW DECCW), 2009, *Climate Change Information Synthesis report for SE (NSW) State Plan Region Integrated Regional Vulnerability Assessment*, November 2009.

Power, K, 2010, *Recycled water use in Australia: regulations, guidelines and validation requirements for a national approach*, Waterlines Report Series No 26, NWC, Canberra.

Public Utility Board (Singapore), 2013, *NEWater*, Singapore's National Water Agency, accessed 21/01/2014, <http://www.pub.gov.sg/water/newater/Pages/default.aspx >, accessed 6 September 2014.

Queensland Department of Energy and Water Supply (DEWS), 2008, *Water Quality Guidelines for Recycled Water Schemes*, Queensland Water Supply Regulator, Brisbane.

Ryan, S, 2011, *Buying Choices for a More Sustainable Canberra*, Report for the ACT Commissioner for Sustainability and the Environment, ACT Government, Canberra.

Water by Design, 2010, *Total Water Cycle Management Planning Guideline for South East Queensland (Version 1, December 2010*), Department of Environment and Resource Management, Brisbane, Queensland.

Yarra Valley Water & Melbourne Water, 2013, *An Integrated Water Future for Melbourne's North – Preliminary Integrated Water Cycle Management Plan*, Office of Living Victoria, Melbourne.

APPENDIX A

SUSTAINABILITY CHARTER

The Belconnen Project Sustainability Vision

"Creating a sustainable community of international significance in the Nation's capital."

The Riverview Group, working with the ACT and NSW Governments, will develop the site at Belconnen to achieve a vision of inspiring sustainable living, development practice and awareness. Achieving a high quality of life for the people living at Belconnen is at the heart of our project planning and design.

We will create a community that exemplifies World's Best Practice in its design, construction and long-term liveability. As a model of sustainable community living it will be a place and community that can be showcased throughout Australia and internationally.

Project objectives:

To achieve our Vision we will challenge conventional industry thinking. We will employ practices, processes and systems that embody innovation and design excellence.

This project has been conceived and will be delivered on a fully integrated and audited triple bottom line basis.

Our project will:

- Be sustainable over time, socially, economically and ecologically (with a low and reducing ecological footprint)
- Respond to the local and global environment
- Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms
- Be cost effective, replicable and measurable
- Act as a new model that others can follow.

elton consulting
Landmatters Pty Ltd
green building council australia
MEMBER 2010-2011

Guiding Principles for Sustainable Results

The principles below will direct decision-making by all project management, sub-consultants and referral agencies in the delivery and development of the Belconnen site. They reflect national priorities and Federal, State and Territory Government policies on housing affordability, climate change and environmental protection.

PARTNERING PRINCIPLES

Ptnr 1. Partnering is essential to this project and the scale and timeframe will allow for positive partnerships to grow and thrive

Ptnr 2. Partnering with public agencies is a cornerstone of our approach

Ptnr 3. Engaging the community in design and governance is fundamental to the delivery of the project.

Ptnr 4. Designing the project for community ownership and ultimate community control

Ptnr 5. Supporting community housing through public and private partnering arrangements

Ptnr 6. Collaborating with research and educational institutions to drive innovation.

EVALUATION PRINCIPLES

Eva 1. Identifying and delivering realistic and costed initiatives

Eva 2. Providing independent peer review of project proposals and project outcomes

Eva 3. Using recognised international and national benchmarks for sustainability performance to publicly report and raise awareness of project outcomes

Eva 4. Empowering resident and community monitoring and management of sustainability performance

Eva 5. Encouraging a culture of continuous improvement.

ECOLOGICAL PRINCIPLES

Eco 1. Acknowledging the intrinsic value of all species and the special role and regional significance of the Murrumbidgee river corridor and Gininnderra Creek

Eco 2. Respecting and supporting the ecosystem functions of air, soil and water, recognising the importance of living and non-living environmental resources

Eco 3. Reducing greenhouse gas emissions through innovative products and place design, material selection and service provision

Eco 4. Recognising our natural ecological limits and minimising our resource, water and energy consumption

Eco 5. Using existing local infrastructure to deliver efficient renewable services and reusable resources

Eco 6. Enhancing local opportunities for food production and production of materials

Eco 7. Fostering a deep sense of respect for and connection to the land, flora and fauna.

SOCIAL AND CULTURAL PRINCIPLES

Soc 1. Respecting and honouring Aboriginal and non-Aboriginal cultural, historical and spiritual values, including integrating with the existing rich, social fabric of Belconnen

Soc 2. Designing for social equity, affordability, diversity and interdependence, honouring differences and catering for the needs of individuals through all stages of life

Soc 3. Maximising health, safety and comfort of the built environment to provide enduring quality of life

Soc 4. Instilling awareness and supporting education of sustainability values, technology and lifestyles

Soc 5. Using creative and robust design solutions to create a continuing sense of place and beauty that inspires, affirms and ennobles

Soc 6. Designing neighbourhoods that support and encourage community interactions through imaginative, functional and enjoyable public spaces

ECONOMIC PRINCIPLES

Econ 1. Delivering a financial return to the ACT Government recognising their sovereign interest in the land

Econ 2. Recognising the opportunities provided by the project's scale and low capital base to achieve high-level sustainability outcomes while delivering profitability to joint venture partners

Econ 3. Building on existing local infrastructure

Econ 4. Ensuring long-term economic viability through design excellence and community building

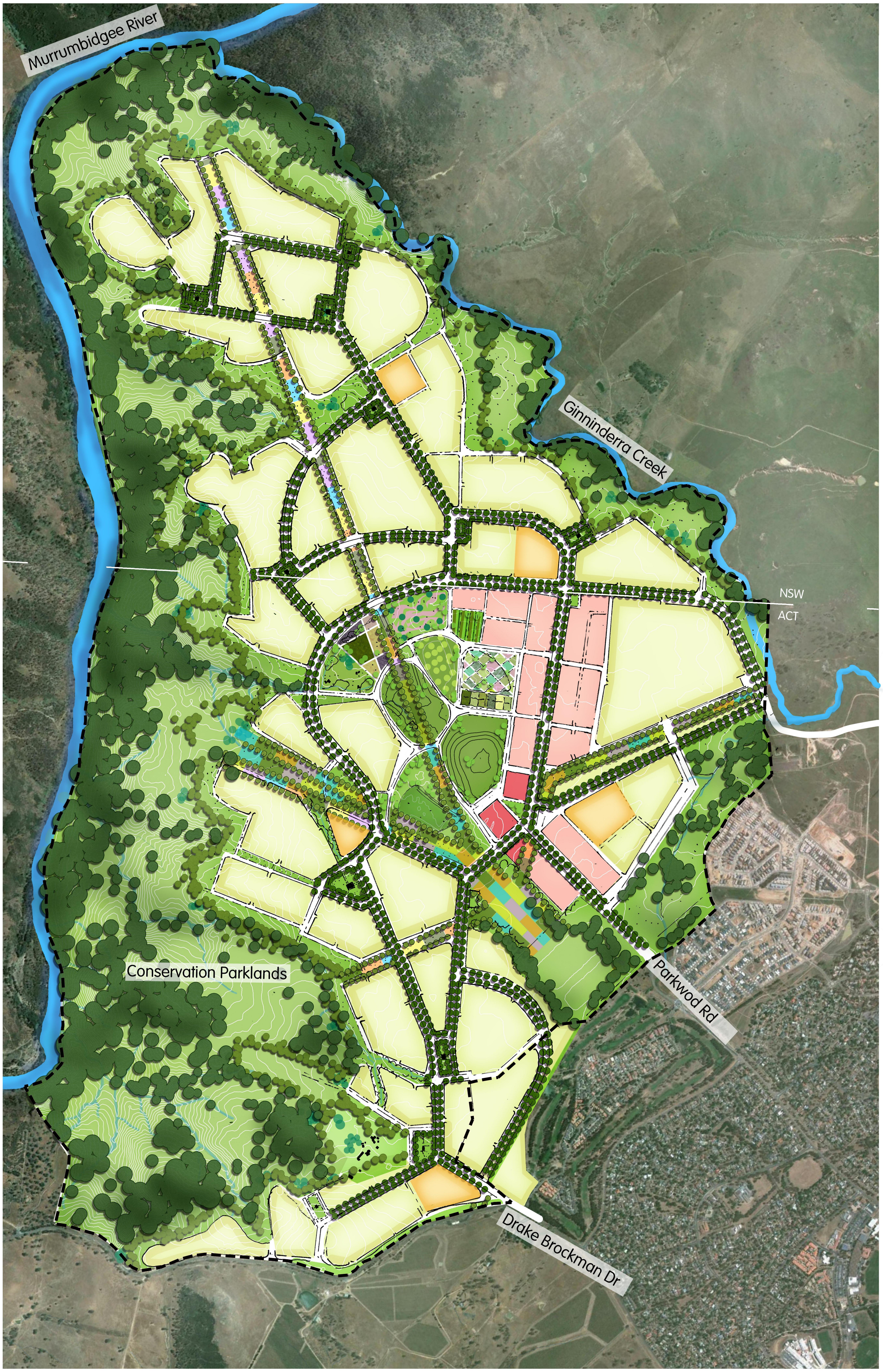
Econ 5. Minimising obsolescence through design of enduring component life cycle, allowing for disassembly and change

Econ 6. Integrating with the Belconnen commercial, retail and employment networks

Econ 7. Growing a formal and informal green economy that fosters local jobs and builds regional learning around green innovation and technology

APPENDIX B

WEST BELCONNEN STRUCTURE PLAN (FEBRUARY 2014)



Key Uses

- 🟨 Garden Suburbs
- 🟧 Education + Community Hubs
- 🟩 Parks + Allotment Gardens
- 🟥 Employment + Mixed Use

Land Development Agency
CANBERRA FIRST

The Riverview Group

RD great places

robertsday.com.au *planning·design·place*

38°
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0 metres 100 200 300 400 500

REV DESCRIPTION YYMMDD DRAWN APPR'D

Illustrative Structure Plan
West Belconnen

REF NO. **RIV BEL**
DRAW NO. **RD1 001**
REV. **A**

APPENDIX C

FINAL WEST BELCONNEN STRUCTURE PLAN (JUNE 2014)

Key Uses

🟨	Garden Suburbs
🟧	Education + Community Hubs
🟩	Parks + Allotment Gardens
🟥	Retail
🟥	Mixed Use
🟥	Potential Mixed Use
🟥	Employment

Land Development Agency
CANBERRA FIRST

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38°
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SIZE A1
0 metres 100 200 300 400 500

REV DESCRIPTION YYMMDD DRAWN APPR'D

Illustrative Master Plan
West Belconnen

REF NO.	DRAW NO.	REV.
RIV BEL	RD1 001	A

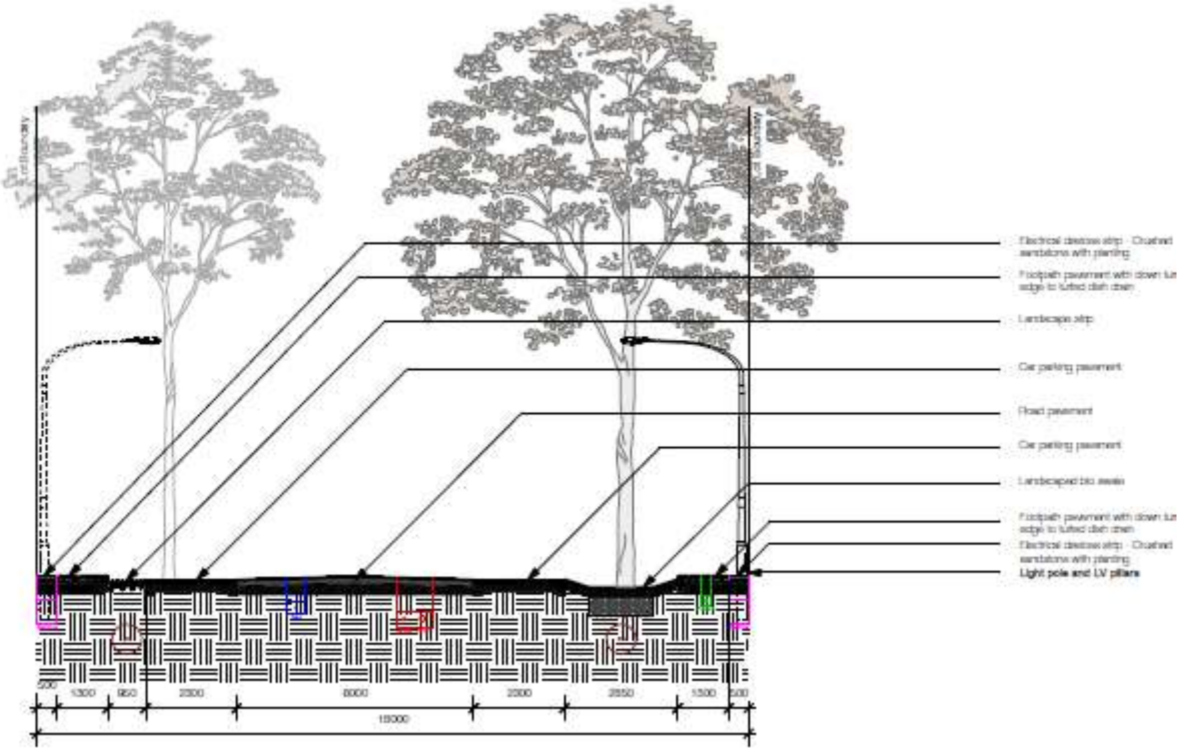
DISCLAIMER: ISSUED FOR DESIGN INTENT ONLY. ALL AREAS AND DIMENSIONS ARE SUBJECT TO DETAIL DESIGN AND SURVEY

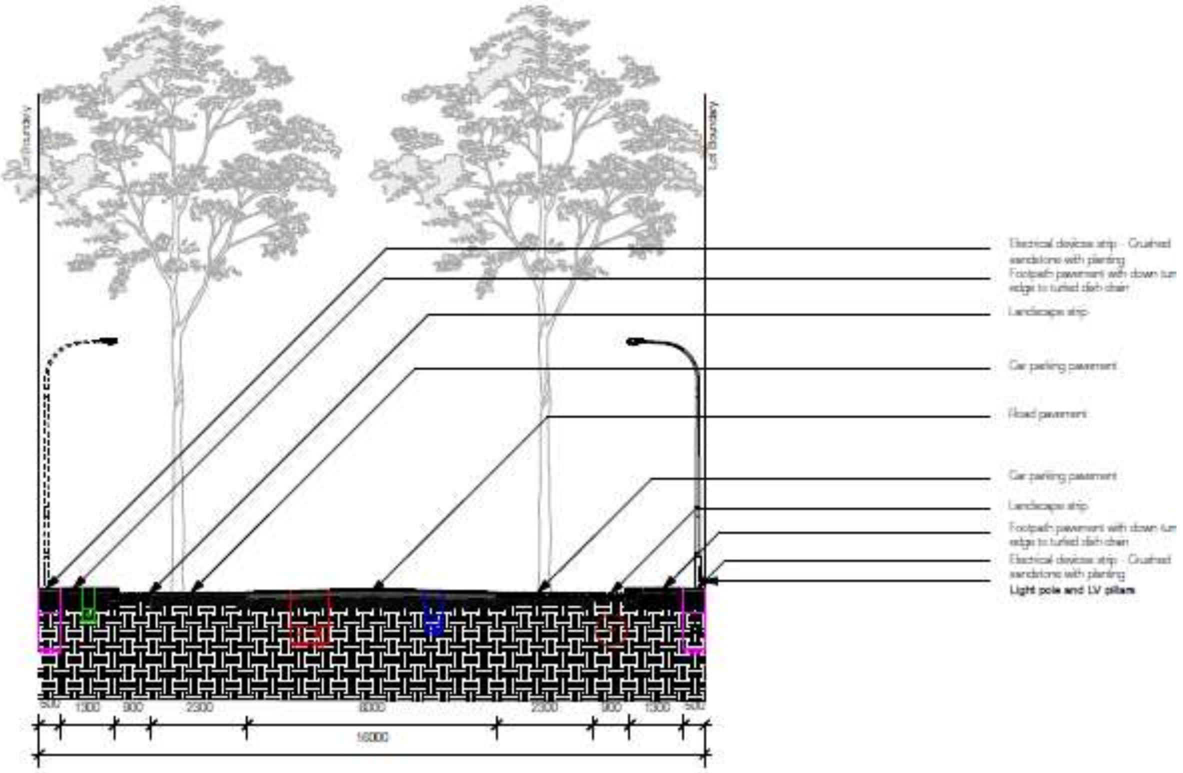
APPENDIX D

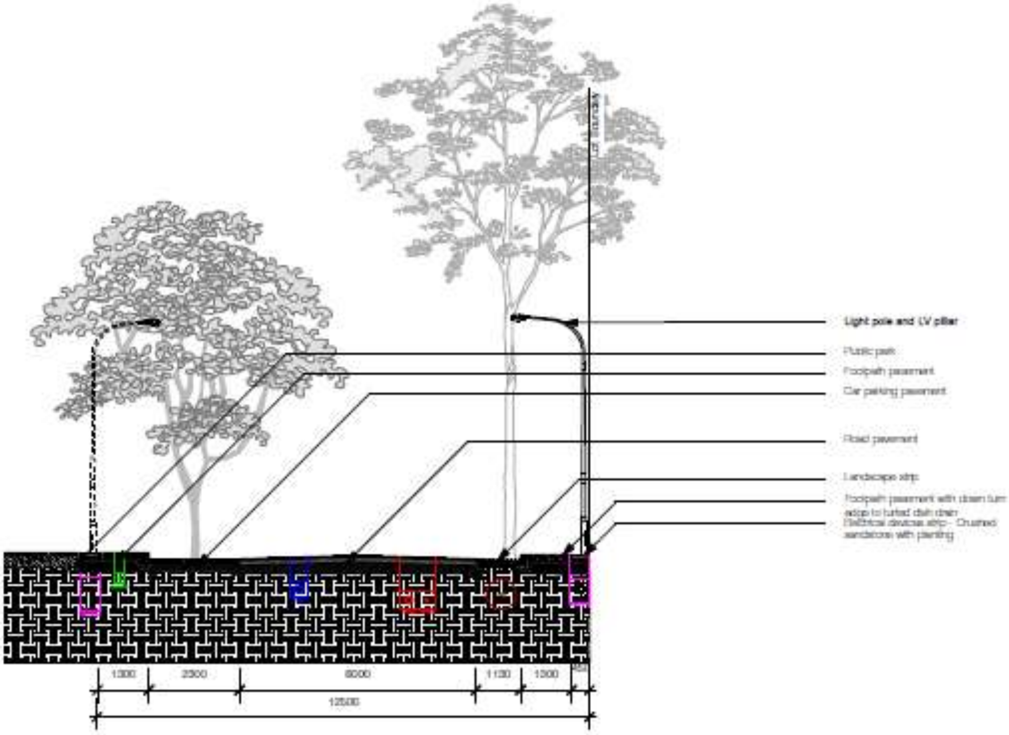
BIOSTREET CONCEPT

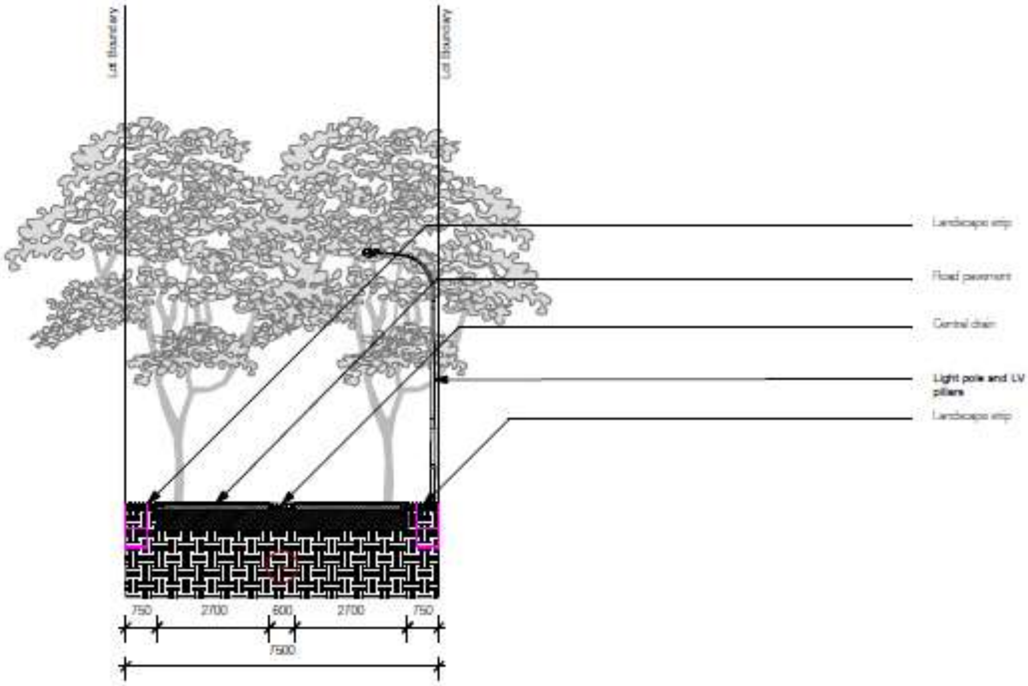
Appendix D Biostreet concept

Figure source: McGregor Coxall, *West Belconnen – Street Typology Comparison*, October 2013






Lot boundary
Light pole and LV pillar
Public path
Footpath pavement
Car parking pavement
Road pavement
Landscape strip
Footpath pavement with drawn turn adap to turfed dish drain
Electrical devices strip - Crushed sandstone with planting
1300
2500
6000
1130
1300
12500


Lot boundary
Lot boundary
Landscape strip
Road pavement
Central drain
Light pole and LV pillars
Landscape strip
750
2700
600
2700
750
7500

APPENDIX E

DECENTRALISED STORMWATER HARVESTING CONCEPT

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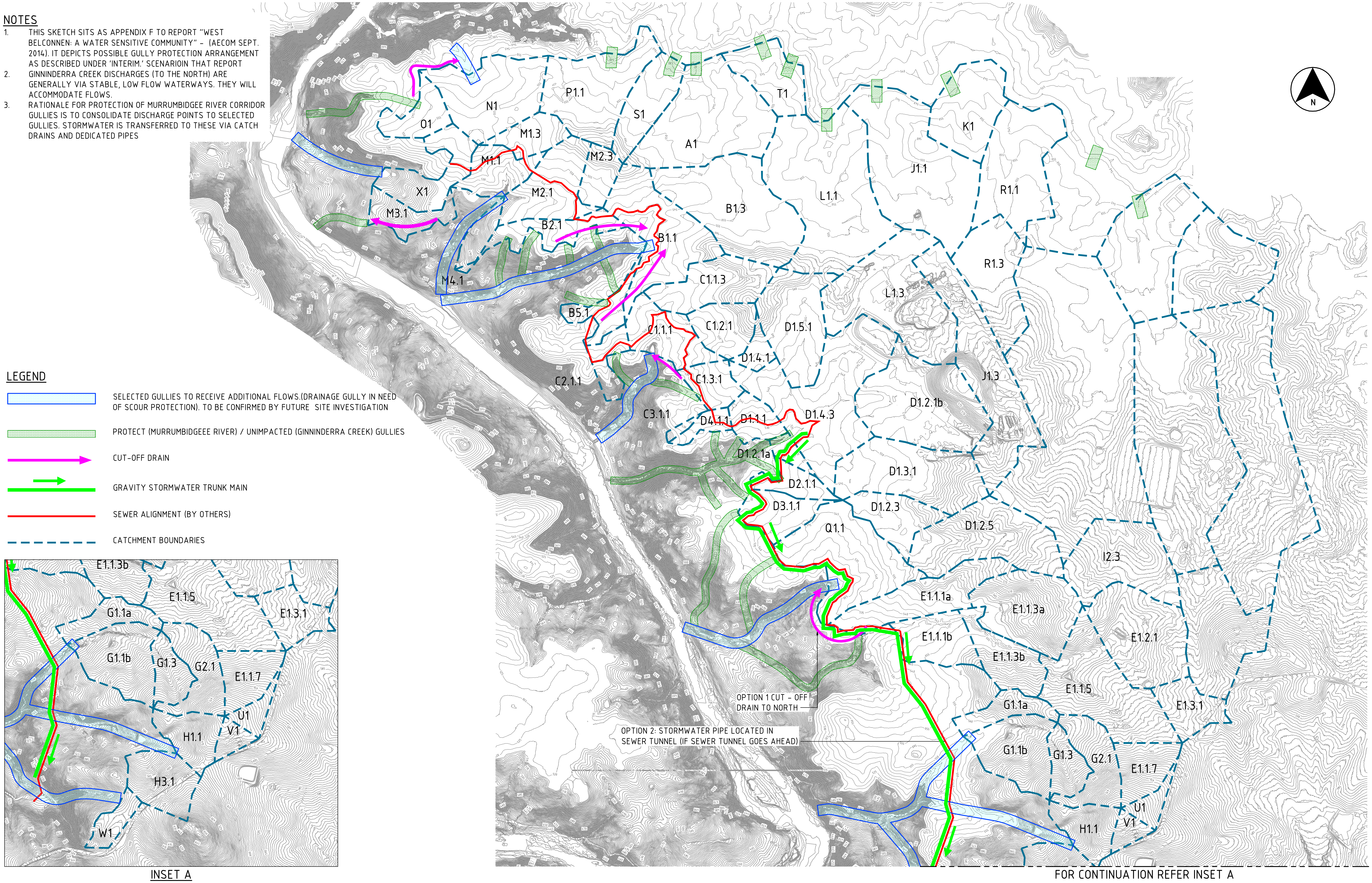
NOTES

1. THIS SKETCH SITS AS APPENDIX F TO REPORT "WEST BELCONNEN: A WATER SENSITIVE COMMUNITY" - (AECOM SEPT. 2014). IT DEPICTS POSSIBLE GULLY PROTECTION ARRANGEMENT AS DESCRIBED UNDER 'INTERIM.' SCENARIOIN THAT REPORT
2. GINNINDERRA CREEK DISCHARGES (TO THE NORTH) ARE GENERALLY VIA STABLE, LOW FLOW WATERWAYS. THEY WILL ACCOMMODATE FLOWS.
3. RATIONALE FOR PROTECTION OF MURRUMBIDGEE RIVER CORRIDOR GULLIES IS TO CONSOLIDATE DISCHARGE POINTS TO SELECTED GULLIES. STORMWATER IS TRANSFERRED TO THESE VIA CATCH DRAINS AND DEDICATED PIPES

LEGEND

🟦	SELECTED GULLIES TO RECEIVE ADDITIONAL FLOWS.(DRAINAGE GULLY IN NEED OF SCOUR PROTECTION). TO BE CONFIRMED BY FUTURE SITE INVESTIGATION
🟩	PROTECT (MURRUMBIDGEEE RIVER) / UNIMPACTED (GINNINDERRA CREEK) GULLIES
→	CUT-OFF DRAIN
→ ━	GRAVITY STORMWATER TRUNK MAIN
━	SEWER ALIGNMENT (BY OTHERS)
- - -	CATCHMENT BOUNDARIES



REVISIONS				
A	DA	11.04.2014	FEASIBILITY STUDY	RS
No.	BY	DATE	DESCRIPTION	APPD

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THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	JL	CHECKED	JL
DRAWN	CH	CHECKED	DA
APPROVED	RS	DATE	25.06.2014

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Contractor :

Client :
The Riverview Group
Land Development Agency
CANBERRA FIRST

Designer :
AECOM
AECOM Australia Pty Ltd
A.B.N. 20 093 846 925

Project
WEST BELCONNEN WSUD

Title
POTENTIAL FLOW DIVERSION AND LINE PROTECTION
INFRASTRUCTURE ARRANGEMENT FOR
'INTERMEDIARY' SCENARIO
SHT 5

Status
FEASIBILITY

Drg No.
60308190-DRG-01-CD0105

Rev.
A

APPENDIX F

DECENTRALISED STORMWATER HARVESTING – RIVER CORRIDOR PROTECTION CONCEPT

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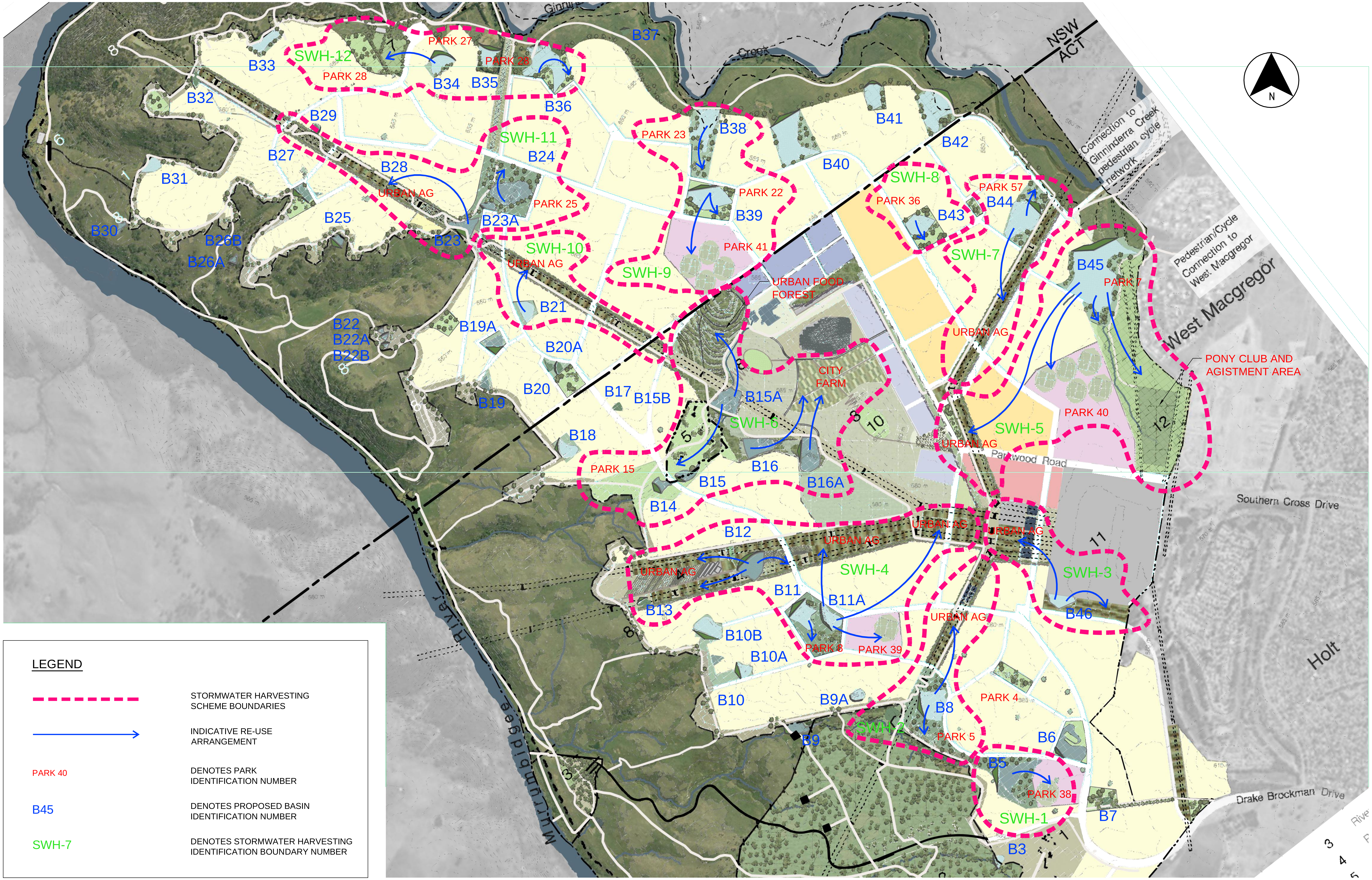

LEGEND

- - - - -	STORMWATER HARVESTING SCHEME BOUNDARIES
→	INDICATIVE RE-USE ARRANGEMENT
PARK 40	DENOTES PARK IDENTIFICATION NUMBER
B45	DENOTES PROPOSED BASIN IDENTIFICATION NUMBER
SWH-7	DENOTES STORMWATER HARVESTING IDENTIFICATION BOUNDARY NUMBER

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
A	DA	11.04.2014	FEASIBILITY STUDY	RS

Scales:

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

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DRAWN	DA	CHECKED	DA
APPROVED	RS	DATE	10.07.2014

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Contractor :

Client :

The Riverview Group

Land Development Agency

CANBERRA FIRST

Designer :

AECOM

AECOM Australia Pty Ltd
A.B.N. 20 093 846 925

Project
WEST BELCONNEN WSUD

Title
POSSIBLE DECENTRALISED
STORMWATER HARVESTING SCHEME

SHT 6

Status
FEASIBILITY

Drg No.
60308190-DRG-01-CD0106

Rev.
A

APPENDIX G

WATER FLOW AND QUALITY PERFORMANCE MONITORING

INSTITUTE FOR
APPLIED ECOLOGY

Proposed Water Quality Monitoring Program for West Belconnen Development

Prepared for AECOM

16th APRIL 2014

UNIVERSITY OF
CANBERRA
AUSTRALIA'S CAPITAL UNIVERSITY

Proposed Water Quality Monitoring Program for West Belconnen Development

Report prepared for: AECOM

Report prepared by: Professor Ross M Thompson

Produced by:

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Front Cover Photograph: Murrumbidgee River at Halls Crossing, 21/3/13.

Introduction

The purpose of this document is to establish the principles for designing a water monitoring program to examine water quality and flow impacts brought about by the West Belconnen development. This program is based on provision of an ongoing program measuring longer term effects coupled with shorter term (construction phase) monitoring to assess any potential impacts of construction activities. Pre-development monitoring is proposed to provide a baseline for assessing change, in addition to data from existing monitoring programs.

The site adjoins two major waterways, Ginninderra Creek to the north and the Murrumbidgee River to the west and south (refer to Figure 1). Two first order waterways flow from the vicinity of Ginninderry Homestead and from near the end of Woodhaven Drive. These are weakly flowing systems in winter and dry to boggy areas in summer. Several intermittent (occasionally flowing) watercourses are associated with shallow gullies, at the northern end of the site in particular. Three of these are of a significant size (likely to transmit surface flow when rainfall events >10mm occur).

Existing water quality monitoring in the area

The ACT government and Waterwatch maintain an extensive network of water quality and aquatic macroinvertebrate monitoring sites across the ACT (Figure 1).

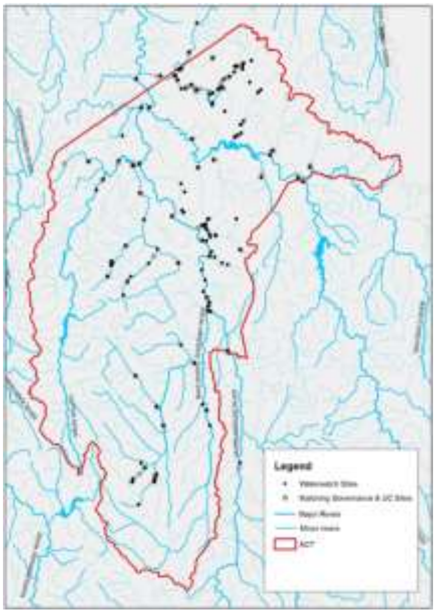

Figure 1. Waterwatch and matching Government water quality sites within the ACT region (from ACT Waterwatch Data Review, Harrison et al. 2013)

Other historical data is available, but is often inappropriate for inclusion in the monitoring proposed here, either because inappropriate parameters were measured or because we cannot be confident that catchments have not changed substantially over the time since samples were taken.

In the direct vicinity of the West Belconnen development there are three relevant sampling sites, which are sampled by Waterwatch and the ACT government at; on the Murrumbidgee River at Uriarra Crossing (upstream of the West Belconnen development), at on the Murrumbidgee River at Halls Crossing (downstream/adjacent to the development) and on Ginninderra Creek at Latham (upstream of the development) (Figure 2). These sites are sampled monthly. Both Waterwatch and ACT government sampling involves measurement of pH, electrical conductivity, dissolved oxygen, temperature, turbidity and concentrations of phosphorus as ortho-phosphate. Waterwatch additionally samples macroinvertebrates which are beyong the scope of the proposed monitoring program. While other sampling has occurred around the site historically, sampling regimes have been intermittent and are often historical (>20 years ago). Waterwatch maintains additional sampling sites at Gooromon Ponds Creek at Dunlop causeway, Jarramlee Pond, via Cashion Ct, Dunlop and Fassifern Pond, via Hugh Mackay Cr, Dunlop, but these are on artificial impoundments not directly relevant to the study proposed here.

Figure 2. Waterwatch and matching Government water quality sites (site codes indicated by number) adjacent to the West Belconnen development site.

Target indicators for water quality

There are a well-established suite of water quality parameters which are known to respond to urbanisation (Table 2). These are associated with disturbance of the site during construction and with runoff from developed areas. Impacts of development include both hydrological impacts (changes in patterns of runoff) and impacts on water quality.

Hydrological impacts. Urbanisation of catchments is associated with an increase in total impervious area (TIA) (roads, rooves, sealed surfaces) which results in increased speed of water runoff and reduced groundwater recharge. This alters the hydrograph of waterways, with faster responses to rainfall and 'flashier' flow regimes. Channels are exposed to higher energy flows, which result in incision of the channel and changes in the composition of sediment, with the loss of moderate sized particles. Streams in urbanised catchments are characteristically steep sided, with fine sediment over very large particles and actively eroding banks. The more efficient transfer of rainfall into stream channels results in increased periods of flow for naturally intermittent streams, which can become in some instances perennial (permanently flowing).

Water quality impacts. Water quality effects of urbanisation can be divided into two phases. During construction, soil disturbance and dust deposition can result in increases in turbidity, sedimentation in the channel and concentrations of iron and phosphorus. Increases in nitrogen may occur depending on soil levels (usually a function of historical landuse). After construction high turbidity and in-channel sedimentation usually persists due to stream bank instability as a consequence of altered hydrology. This can be contributed to by any soil disturbance in the catchment, which also contributes to increased phosphorus loads. Nitrogen concentrations in urban streams are increased by organic matter inputs (e.g. from leaf material, particularly exotic hardwood species) and inputs from fertiliser inputs. High organic inputs may also result in increased biochemical oxygen demand (BOD) and reduce dissolved oxygen concentrations. Stormwater runoff from impervious surfaces is characterised by high concentrations of a suite of heavy metals (particularly lead, zinc, cadmium and copper) which results in increased values for conductivity. Some urban situations (particularly where there are septic tank discharges, cross contamination of sewage infrastructure and stormwater or stock waste inputs) may show heightened levels of *Escherichia coli* (*E.coli*), an intestinal bacteria. Some types of *E.coli* are associated with food poisoning, and their presence indicates potential contamination of surface waters by other bacteria with associated public health risks.

Thermal impacts. Urbanisation is commonly associated with increases in stream temperatures. This effect is a result of loss of streamside vegetation, water flowing from warm impervious surfaces and reductions in inflows from cooler groundwater. Urban settings are also associated with warmer air temperatures as a consequence of the 'urban heat island effect' which can also increase stream temperatures.

Table 2. Summary of water indicators known to be sensitive to urbanisation of catchments, with main methods for measurement.

Target indicator	**Responds to**	**Measurement**
Hydrograph	Increases in impervious surfaces	Continuous stage logger Established gauges
Turbidity	Soil disturbance Bank erosion Dust deposition	Continuous logger OR Hand-held meters
Conductivity	Impervious surface runoff Increased concentration of ions, including heavy metals	Continuous logger OR Hand-held meters
Dissolved oxygen	Changes in organic matter supply Biochemical oxygen demand	Continuous logger OR Hand-held meters
Total nitrogen	Impervious surface runoff Sewage contamination Fertiliser application	Water sample for laboratory analysis
Total phosphorus	Soil disturbance Sewage contamination Fertiliser application	Water sample for laboratory analysis
Heavy metals (lead, cadmium, zinc, copper)	Impervious surface runoff	Water sample for laboratory analysis
Escherichia colii	Sewage contamination	Water sample for laboratory analysis
Temperature	Impervious surface runoff Loss of riparian vegetation Reduced groundwater flow	Continuous loggers OR Hand-held meters

Proposed monitoring program for West Belconnen

Underlying principles

The monitoring program proposed is based on BACI principles (Before-After-Control-Impact) with upstream 'control' sites coupled with downstream 'impact' sites on the two main water courses (Ginninderra Creek and the Murrumbidgee River) (Figure 1, Table 3). Sampling at these locations will begin before development and continue through after completion. Additional sites will be monitored targeting changes through the period of development, but without paired control sites.

These are the two first order streams (First order creek A,B) and three gully sites (Gully Site A,B,C) (Figure 1). Additional monitoring will occur at the inlets and outlets of the treatment ponds and will target compliance and assessment of the effectiveness of the treatment chain (Table 4).

Figure 1. Spatial design of proposed water quality monitoring program for the West Belconnen development. For a key to the symbols see Table 2.

Location of sites

Sampling takes advantage of existing sampling sites for the upstream and downstream sites in the Murrumbidgee River and for the upstream site on Ginninderra Creek. An additional site is proposed downstream on Ginninderra Creek near the confluence with the Murrumbidgee River. Other sampling is targeted to sites where any changes in hydrology (e.g. gullys, small streams) and to the ilet and outlet of the stormwater treatment chain (or chains).

Frequency of sampling

Continuous samplers will be deployed at the paired sites on the main watercourses. This sampling will be supplemented by spot measurements taken at different intervals depending on the phase of the works. Frequency of sampling will be aimed pre-construction at gaining sufficient data for comparisons during and after construction, and will therefore occur weekly. During the construction phase, parameters of particular interest will be monitored weekly, but this program will be relaxed to monthly sampling of most parameters after construction. Some parameters will not be sampled after the construction phase, and it is expected that some sampling sites will be removed one year and 5 years after completion (Table 3).

It is now well known that rainfall events are often associated with peaks in key water quality parameter values. As a result, an event-based sampling regime is proposed with all events >10mm sampled before and during construction, and for the first year after completion.

Justification of scope of sampling by parameter

Hydrograph. Assessing a hydrograph adequately requires extensive infrastructure. This monitoring program will rely on established gauges upstream and downstream of the development to assess any effects on hydrology in the Murrumbidgee River. Continuous loggers placed in the small streams and gullies on the site will provide an assessment of whether there are large changes in the patterns of runoff from the site after development. The loggers on the gully sites will be removed 1 year after completion, with the loggers on the small streams removed after 5 years.

Turbidity. Turbidity is of key concern during construction. Continuous logging, weekly and event based sampling before construction begins will provide baseline data, and will be a point of comparison with sampling during the construction phase. As turbidity impacts may persist for some years after development, sampling is planned to continue, although at a reduced frequency until 5 years after completion (Table 3).

Conductivity. Conductivity can be effectively logged using a continuous data logger and provides some indication of the levels of nutrients and metals. The low cost of this activity and the potential for it to indicate problem levels of contaminants without expensive laboratory processing means that monitoring is continued throughout the program.

Dissolved oxygen. Dissolved oxygen is of considerable concern where high organic matter loads lead to deoxygenation of the water column. Modern techniques allow relatively simple continuous monitoring of this parameter.

Total nitrogen and phosphorus. Concerns over these nutrients are usually associated with the potential to cause nuisance algal growth. Weekly sampling in the pre-construction phase is intended to establish baseline levels. The high expense of sample processing means that monthly sampling is planned after the works begin.

Heavy metals (lead, cadmium, zinc, copper). Concerns over these contaminants are associated with the building phase and effects of stormwater runoff from impervious surfaces after completion of works. Weekly sampling in the pre-construction phase is intended to establish baseline levels. The high expense of sample processing means that monthly sampling is planned after the works begin.

Escherichia colii. E colii is of particular concern in the Murrumbidgee River due to public health risk from recreation. The very high cost of this sampling means that the program is highly targeted towards the running water sites. Repeated absences over the first year of sampling after completion may lead to reducing the sampling to the downstream Murrumbidgee site only.

Temperature. Temperature is relatively simply and cheaply measured, and is required to interpret other parameters (e.g. dissolved oxygen).

Table 3. Summary of proposed water quality monitoring program for West Belconnen. Symbols relate to locations in Figure 1. 'Weekly' and 'Monthly' indicate the intervals of spot measurements for those parameters, 'event' indicates sampling when rainfall exceeds 10mm in a 24h period. Blank indicates a parameter is not measured.

Location	▲	●	○
Infrastructure	Continuous loggers for temperature, turbidity, conductivity, dissolved oxygen, nutrient	Continuous loggers for water depth, temperature, turbidity, conductivity,	Continuous loggers for water depth

	sampling	dissolved oxygen	
PRE CONSTRUCTION			
Hydrograph	Uses existing gauges	Continuous logger	Continuous logger
Turbidity	Continuous	Continuous	Weekly + event
Conductivity	Continuous	Continuous	Weekly + event
Dissolved oxygen	Continuous	Continuous	Weekly + event
Total nitrogen	Weekly + event	Weekly + event	
Total phosphorus	Weekly + event	Weekly + event	
Heavy metals	Weekly + event	Weekly + event	
Escherichia colii	Weekly + event		
Temperature	Continuous	Continuous	
DURING CONSTRUCTION			
Hydrograph	Uses existing gauges	Continuous logger	Continuous logger
Turbidity	Continuous	Continuous	Weekly + event
Conductivity	Continuous	Continuous	Weekly + event
Dissolved oxygen	Continuous	Continuous	Weekly + event
Total nitrogen	Monthly + event		
Total phosphorus	Monthly + event		
Heavy metals	Monthly + event		
Escherichia colii	Monthly + event		
Temperature	Continuous	Continuous	
POST CONSTRUCTION			
Hydrograph	Uses existing gauges	Continuous logger[2]	Continuous logger[3]
Turbidity	Continuous[1]	Continuous[2]	Monthly + event[3]
Conductivity	Continuous[1]	Continuous[2]	Monthly + event[3]
Dissolved oxygen	Continuous[1]	Continuous[2]	Monthly + event[3]
Total nitrogen	Monthly + event[1]		
Total phosphorus	Monthly + event[1]		
Heavy metals	Monthly + event[1]		
Escherichia colii	Monthly + event[1]		
Temperature	Continuous[1]	Continuous[2]	

1. *It is intended that the additional upstream sampling location (if needed, see note below) on the Murrumbidgee River and both sampling locations on Ginninderra Creek will be removed after 5 years. The remaining Murrumbidgee site would be maintained into the future (see note below).*
2. *Sampling to cease 5 years after completion.*
3. *Sampling to cease 1 year after completion.*

Table 4. Summary of proposed water quality monitoring program for the treatment chain at West Belconnen. 'Monthly' indicates the intervals of spot measurements for those parameters, 'event' indicates sampling when rainfall exceeds 10mm in a 24h period. Blank indicates a parameter is not measured.

Location	Treatment chain inlet	Treatment chain outlet
Infrastructure	Continuous loggers for temperature, turbidity, conductivity, dissolved oxygen	Continuous loggers for temperature, turbidity, conductivity, dissolved oxygen

Hydrograph		
Turbidity	Continuous	Continuous
Conductivity	Continuous	Continuous
Dissolved oxygen	Continuous	Continuous
Total nitrogen	Monthly + event	Monthly + event
Total phosphorus	Monthly + event	Monthly + event
Heavy metals	Monthly + event	Monthly + event
Escherichia colii	Monthly + event	Monthly + event
Temperature	Continuous	Continuous

Redundancy and efficiencies

Sampling in the pre-construction phase will directly assess the relationship between values recorded at the newly established monitoring site, and values from established upstream monitoring sites. Where these values are closely correlated, then the new site may be able to be disestablished. Note that this is unlikely – the nearest existing monitoring site is considerably upstream on Ginninderra Creek.

Delivery and ownership of the monitoring program and data generated

It is recommended that the data collection be integrated with existing programs run from the ACT government from the outset, building on the data storage capacity already present. It is recommended that the ACT government be engaged with at completion to develop the downstream Murrumbidgee site as an ongoing monitoring site, with community engagement from the West Belconnen community.

REFERENCES

Harrison, E., Dyer, F., Gruber, B., Nichols, S., and Tschierschke, A., (2013) ACT Waterwatch Data Review. Report prepared for: ACT Waterwatch

BUDGET

Set-up costs

Continuous multiparameter loggers 8 sites @ $8000/site	$64,000
Continuous depth loggers 3 sites @ $1000/site	$ 3,000
Dedicated logger Horiba UX-10 @ $10000	$10,000
Software and support for loggers	$ 5,000

Monitoring costs

Year 1

Weekly sampling labour 52 weeks x 2 people @ $1000/day	$52, 000
Event sampling labour 10 events x 2 people @ $1000/day	$ 10,000
Water quality analysis 52 weeks x 11 sites x $100/site	$57,200
Water quality analysis 10 events x 11 sites x $100/site	$11,100
Reporting and analysis 7 days x 1 person x $500/day	$ 3,500

Year 2

Monthly sampling labour 12 months x 2 people @ $1000/day	$ 24, 000
Weekly sampling labour 52 weeks x 2 people @ $500/day	$ 52,000
Event sampling labour 10 events x 2 people @ $1000/day	$ 10,000
Water quality analysis 12 months x 8 sites x $100/site	$ 9,600
Water quality analysis 52 weeks x 3 sites x $50/site	$ 7,800
Water quality analysis 10 events x 11 sites x $100/site	$11,100
Reporting and analysis 7 days x 1 person x $500/day	$ 3,500

Year 3

Monthly sampling labour 12 months x 2 people @ $1000/day	$ 24, 000
Weekly sampling labour 52 weeks x 2 people @ $500/day	$ 52,000
Event sampling labour 10 events x 2 people @ $1000/day	$ 10,000
Water quality analysis 12 months x 8 sites x $100/site	$ 9,600
Water quality analysis 52 weeks x 3 sites x $50/site	$ 7,800
Water quality analysis 10 events x 11 sites x $100/site	$11,100
Reporting and analysis 7 days x 1 person x $500/day	$ 3,500

Year 4

Monthly sampling labour 12 months x 2 people @ $1000/day	$24, 000
Event sampling labour 10 events x 2 people @ $1000/day	$ 10,000
Water quality analysis 12 months x 11 sites x $100/site	$13,200
Water quality analysis 10 events x 11 sites x $100/site	$11,100
Reporting and analysis 7 days x 1 person x $500/day	$ 3,500

Year 5

Monthly sampling labour 12 months x 2 people @ $1000/day	$24, 000
Event sampling labour 10 events x 2 people @ $1000/day	$ 10,000
Water quality analysis 12 months x 11 sites x $100/site	$13,200
Water quality analysis 10 events x 11 sites x $100/site	$11,100
Reporting and analysis 7 days x 1 person x $500/day	$ 3,500

APPENDIX H

NON-TURF CROP IRRIGATION DEMAND CALCULATIONS

Appendix H Non-turf crop irrigation demand calculations

The *ACT Water Act* 2007 Schedule 1 determines that the volume of water for irrigation of public open space parkland, sportsgrounds and residential gardens is considered to be 0.5 ML/1,000 m^2 *per annum.*

To understand the irrigation requirements in an ACT context for other types of crops it was necessary to develop a measure of evapotranspiration for the ACT climate for a range of plants. The Penman-Monteith method has been used to determine a reference evapotranspiration (ET_0) from local meteorological data.

The Food and Agriculture Organisation of the United Nations (FAO) recommends the Penman-Monteith method be the sole standard method for measuring ET_0. This is resultant of studies undertaken by the American Society of Civil Engineers (ASCE) and European studies that show the method provides dependable and consistent performance in both arid and humid climates[25].

The Penman-Monteith equation requires air temperature, humidity, radiation and wind speed for daily, weekly, ten-day or monthly calculations. The altitude above sea level and latitude of the location should also be specified. When the standard ET_0 is determined, the crop coefficients (K_C, collated from FAO) can be used to calculate the specific crop evapotranspiration (ET_C) from the calculated ET_0 i.e. $ET_C= K_C$ xET_0. Therefore, the crop's irrigation requirements are determined by subtracting the average rainfall from the crop's ET_C.

Climate figures for the Canberra region were determined using rainfall data obtained from the Bureau of Meteorology for the period 1968 to 1977. The ET_0 was calculated and this data is shown in the first table below. Subsequently, irrigation water requirements were determined for a variety of vegetables and fruit trees. These requirements are shown in in the second table.

From the analysis it is evident that crops require more irrigation throughout the summer months (December, January and February) and require little or no irrigation throughout the winter months (June, July and August). Crops that require the greatest source of irrigation water include tomatoes, potatoes, peas, mint, apple/cherry/pear trees and stone fruit trees. Crops that require very little irrigation include cantaloupe, strawberries, citrus trees and olive trees. Cumulatively, vegetable crops will require an additional 586 mm of water *per annum* in irrigation and fruit trees would require an additional 559 mm *per annum*.

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[25] Refer to the FAO Penman-Monteith method discussion at: http://www.fao.org/docrep/x0490e/x0490e06.htm, accessed September 2014

Table H1: ACT rainfall, evapotranspiration and rainfall deficit data (Canberra Airport 1968-1977)

Parameter	Unit	Climate data											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Duration of Month	Days	31	28	31	30	31	30	31	31	30	31	30	31
Avg Rainfall	Mm	63	55	54	51	49	38	42	46	51	66	64	53
ET_0	Mm	176.4	140	119	74.9	47.6	32.2	36.4	56	78.4	110.6	135.1	175
Rainfall deficit	Mm	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122

Table H2: Irrigation requirements for selected crops based on ACT climate

Vegetables and Fruit	K_C	Irrigation water requirement (mm)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Broccoli	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Brussel Sprouts	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Cabbage	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Carrots	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Cauliflower	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Celery	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Garlic	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Lettuce	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Onions	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Spinach	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Radish	**0.9**	95.76	71	53.1	16.41	0	0	0	4.4	19.56	33.54	57.59	104.5
Egg Plant	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Sweet Peppers (bell)	**1.05**	122.57	92.28	71.19	27.79	1.08	0	0	12.91	31.4768	50.351	78.1252	131.1

Vegetables and Fruit	K_C	Irrigation water requirement (mm)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tomato	**1.15**	140.21	106.28	83.09	35.28	5.84	0	0	18.51	39.3168	61.411	91.6352	148.6
Cantaloupe	**0.85**	86.94	64	47.15	12.67	0	0	0	1.6	15.64	28.01	50.835	95.75
Cucumber	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Pumpkin, Winter Squash	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Squash, Zucchini	**0.95**	104.58	78	59.05	20.16	0	0	0	7.2	23.48	39.07	64.345	113.25
Sweet Melons	**1.05**	122.22	92	70.95	27.65	0.98	0	0	12.8	31.32	50.13	77.855	130.75
Watermelon	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Potato	**1.15**	139.86	106	82.85	35.14	5.74	0	0	18.4	39.16	61.19	91.365	148.25
Chick pea	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Peas	**1.15**	140.21	106.28	83.09	35.28	5.84	0	0	18.51	39.3168	61.411	91.6352	148.6
Artichokes	**1**	113.4	85	65	23.9	0	0	0	10	27.4	44.6	71.1	122
Asparagus	**0.96**	105.81	78.98	59.88	20.68	0	0	0	7.592	24.0288	39.844	65.2907	114.475
Mint	**1.15**	139.86	106	82.85	35.14	5.74	0	0	18.4	39.16	61.19	91.365	148.25
Strawberries	**0.85**	86.94	64	47.15	12.67	0	0	0	1.6	15.64	28.01	50.835	95.75
Average		**117.08**	**87.92**	**67.49**	**25.47**	**1.19**	**0**	**0**	**11.17**	**29.04**	**46.91**	**73.92**	**125.65**
TOTAL													**585.84**

Fruit Trees	k_C	Irrigation water requirement (mm)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Almonds, no ground cover	**0.9**	95.76	71	53.1	16.41	0	0	0	4.4	19.56	33.54	57.59	104.5
Apples, Cherries, Pears	**1.2**	148.68	113	88.8	38.88	8.12	0.64	1.68	21.2	43.08	66.72	98.12	157
Apricots, Peaches, Stone Fruit	**1.15**	139.86	106	82.85	35.14	5.74	0	0	18.4	39.16	61.19	91.365	148.25
Citrus, with active ground cover or weeds	**0.8**	78.12	57	41.2	8.92	0	0	0	0	11.72	22.48	44.08	87
Olives (40 to 60% ground coverage by canopy)	**0.7**	60.48	43	29.3	1.43	0	0	0	0	3.88	11.42	30.57	69.5
Pistachios, no ground cover	**1.1**	131.04	99	76.9	31.39	3.36	0	0	15.6	35.24	55.66	84.61	139.5
Walnut Orchard	**1.1**	131.04	99	76.9	31.39	3.36	0	0	15.6	35.24	55.66	84.61	139.5
Average		**112.14**	**84**	**64.15**	**23.37**	**2.94**	**0.1**	**0.24**	**10.75**	**26.84**	**43.81**	**70.14**	**120.75**
TOTAL													**559.23**