Development of Practical Solutions for the North East of Victoria – adapting to a low water future

Water security

For the North East Greenhouse Alliance

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Glossary of Terms and acronyms

0%:	**Zero Percent Population Growth Scenario.** A scenario which tests the implications of no change in population of North East Victoria to 2050.
2%:	**Two Percent Population Growth Scenario.** A scenario which tests the implications of 2% annual growth in population of North East Victoria to 2050.
ABS:	**Australian Bureau of Statistics.** Australia's national statistical agency.
WEA:	**Option that includes water efficiency.** A building scale intervention that includes water efficient appliances and gardens.
RWH:	**Option that includes rainwater harvesting.** Building level intervention that includes rainwater harvesting.
BAU:	**Business as Usual.** The Option that accounts for the current state and approach water cycle management.
Blackwater:	Wastewater generated by the toilet.
BOD:	**Biological Oxygen Demand.** A chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. Widely used as an indication of the organic quality of water.
BWA:	**Bulk Water Authority.** The water authority responsible for providing bulk water services to North East Victoria. This is Goulburn Murray Water.
CC:	**Climate Change.** A long-term change in the statistical distribution of weather patterns over periods of time.
CPI:	**Consumer Price Index.** A social and economic indicator that aims to measure the change in consumer prices and goods over time.
NEW:	**North East Water.** The Retail Water Authority responsible for providing retail water services to North East Victoria.
DPCD:	**Department of Planning and Community Development.** The Victorian Government agency responsible for managing the State's planning system.
DSE:	**Department of Sustainability and the Environment.** The Victorian Government agency responsible for sustainable management of Victoria's water resources and catchments, climate change, bushfires, parks and other public land, forests, biodiversity and ecosystem conservation.
EC:	**Economic Structural Change Scenario.** A modelling scenario which tests the implications of a restructure in the economy of North East Victoria from (water intensive) manufacturing into other sectors.
EPA:	**Environmental Protection Authority of Victoria.** The Victorian Government agency responsible for the protection, care, and improvement of Victoria's environment.

ESC: **Essential Services Commission.** Victoria's price regulator responsible for determining the prices and charging arrangements for provision of water services.

Greywater: is generated by residential kitchens, bathrooms and laundries.

HE: **High Emissions Climate Change Scenario.** Tests the impact of the IPCC's upper bounds temperature increases on the water cycle in North East Victoria.

IWCM: **Option that includes Integrated Water Cycle Management.** A multi-disciplinary and multi-objective approach for the sustainable use of available resources with the objectives of environmental protection, water supply, stormwater management and wastewater treatment.

LE: **Low Emissions Climate Change Scenario.** A modelling scenario which tests the impact of the IPCC's lower bounds temperature increases on the water cycle in North East Victoria.

LGA: **Local Government Area.** An administrative division defined by the Australian Bureau of Statistics that a local government is responsible for.

MBR: **Membrane Bioreactor.** A modular wastewater treatment process which combines a membrane process such as microfiltration or ultra filtration with a suspended growth bioreactor. Widely used for municipal and industrial wastewater treatment.

NWC: **The National Water Commission.** A Statutory Authority established by the Australian Government in 2004 to provide advice on and drive progress towards the sustainable management and use of Australia's water resources.

Option: A modelling technique which are established to test, compare and contrast a range of alternative future states.

Roofwater: Rainfall collected from the roofs of buildings.

RWT: **Rainwater tank.** A water tank which is used to collect and store rainwater runoff, typically from rooftops via rain gutters.

SCADA: **Supervisory Control And Data Acquisition**. Control and computer systems that monitor and control industrial, infrastructure, or facility-based processes.

Scenario: A modelling technique established to provide a more detailed understanding of potential opportunities. Constraints including governance arrangements, institutional frameworks and organisational capabilities are introduced to test the practicality of Options.

Stormwater: Rainfall that runs off all urban surfaces such as roofs, pavements, carparks, roads, gardens and vegetated open space.

TDS: **Total Dissolved Solids.** A measure of the combined content of all inorganic and organic substances contained in a given water sample at certain temperature over a specific time period.

TN: **Total Nitrogen.** The sum of the nitrogen present in all nitrogen-containing components in a given water sample at certain temperature over a specific time period.

TSS: **Total Suspended Solids.** A water quality measurement which measure of the mass of fine inorganic particles suspended in a given water sample at certain temperature over a specific time period.

WSDS: **Water Supply Demand Strategy.**

Wastewater: A combination of Greywater and Blackwater and may include wastewater from non-residential allotments such as used water and sewage that goes down sinks, toilets and outside drains which enters the wastewater system or septic tanks if a dwelling is not connected to the wastewater network.

WSAA: **Water Services Association of Australia**. The industry peak body which represent Australian water authorities. As part of their activities WSAA releases a set of Benchmarking Reports, which are audited annual reports that benchmark Australian water utilities across a range of agreed and consistent parameters.

WSUD: **Water Sensitive Urban Design.** Design principles that aim to reduce the impact of interactions between the urban built form and the urban water cycle as defined by the three urban water streams of potable water, wastewater and stormwater.

WWTP: **Wastewater Treatment Plant.** A centralised wastewater treatment plant operated by North East Water or other responsible entity.

Contents

Executive summary

The North East Greenhouse Alliance commissioned Dr. Peter Coombes and Bonacci Water to investigate options for improving water security and adapting to a low water future throughout the North East region. This "Adapting to a Low Water Future" project is funded by the Australian Government's "Strengthening the Basin Communities" component of the "Water for the Future" program. The project is being delivered by the North East Greenhouse Alliance on behalf of the City of Wodonga, Rural City of Wangaratta and Alpine, Indigo, Towong Shires in partnership with the North East Catchment Management Authority, North East Water and Goulburn Murray Water.

The North East region of Victoria has one of the most secure water supplies in Victoria and the Murray Darling Basin. Major water storages include: Lake Dartmouth , Lake Hume, Lake Buffalo, Lake Mulwala and Lake William Hovell in addition to storages associated with the Kiewa Hydro Electric Scheme. The intent of this report is to determine how larger towns may use this valuable national resource more efficiently, and to identify options and strategies for some smaller communities geographically separated from these major storages and the river flows they contribute to.

For serviced towns local strategies were generally resilient to the impacts of climate change. A forensic analysis has been undertaken of the existing biophysical systems that are related to North East Victoria. The analysis incorporates inputs from many disciplines, to understand the potential futures of towns in the region.

The existing sophisticated integrated systems models of the North East region developed by Dr Peter Coombes have been updated and enhanced for use in this project. These models subdivide the region into hierarchies of distributed nodes, or 'zones', that represent opportunities, constraints and feedback loops across multiple scales. A selection of indicative alternative Options; WEA, RWH, WWR and IWCM; were compared to the business as usual (BAU) Option to understand the response of the North East Victorian system to alternative strategies. The alternative Options considered in this investigation are:

WEA – this Option includes water efficient buildings, gardens and practices and rainwater in all new and redeveloped buildings.

RWH – this Option combines the WEA Option with rainwater harvesting to supply laundry, toilets and outdoor uses in all new and developed buildings.

WWR – this Option combines the WEA Option with wastewater reuse to supply outdoor uses in all new and developed buildings.

SWH – this Option combines the WEA Option with stormwater harvesting to supply toilets and outdoor uses in all new and developed buildings.

IWCM – this Option combines the WEA Option with wastewater reuse for toilet and outdoor uses with rainwater harvesting to supply the remaining indoor water uses in all new and developed buildings.

The analysis revealed that annual rainfall is highly variable over time and throughout North East Victoria. It is also clear that the region has not been subject to a "step change" in rainfall regimes.

The climate change scenarios modelled generate moderate reductions in average annual rainfall and large reductions in streamflow in rivers by 2050. This result indicates that the availability of regional water resources will be dramatically diminished by 2050.

Climate change scenarios generated insignificant reductions in the yields from rainwater harvesting, considerable reductions in stormwater runoff and small increases in outdoor water use.

There is sufficient depth of annual rainfall, even during low rainfall years, for significant rainwater and stormwater yields at all locations throughout North East Victoria.

A summary of the results of this study is presented below:

Climate

1. The recent drought reduced average annual rainfall by 4.8% to 19.5% throughout North East Victoria and included a 4% (0.9°C) increase in average daily maximum temperatures.
2. Increases in temperaure and evaporation with reduced rainfall in the recent drought reduced annual average streamflow in rivers by 16.5% to 37.9%.
3. The recent drought may not be the worst period of low rainfall on record at many locations throughout North East Victoria and is consistent with the cycles of natural variation in rainfall.
4. The rainfall records in the North East region do not reveal evidence of a step change in rainfall regimes.
5. The region is subject to a high frequency of rainfall events (on average, every 3 to 6 days) and is eminently suitable for highly efficient rainwater and stormwater harvesting strategies.
6. Climate change may generate reductions in annual average rainfall of 9% to 18% and diminish annual average streamflows by 25% to 45% by 2050. It is noteworthy that these scenarios produce years with very low flows in the region's rivers that is consistent with more severe droughts.

Lot Scale Analysis

7. Although climate change generates large reductions in average annual streamflows in rivers, the reduction in average annual yields from rainwater harvesting was insignificant ranging from 0.3% to 4.8%. In contrast reductions in stormwater runoff ranged from 13.2% to 28.7%. Local strategies were resilient to the impacts of climate change.
8. Climate change also generated small increases in outdoor water use ranging from 3.9% to 7.5%.
9. Water efficient buildings, gardens and practices reduces demands for reticulated water by 31% to 34% and decreases wastewater discharges by 25%.
10. Rainwater harvesting with water efficient buildings, gardens and practices generated considerable reductions in water demands (58.9% to 64%) with diminished wastewater discharges (25%) and stormwater runoff (17% to 45.4%).
11. Wastewater reuse with water efficient buildings, gardens and practices generated significant reductions in water demands (41.1% to 52.3%) with diminished wastewater discharges (38.7% to 53.7%).

12. A combination of rainwater harvesting and wastewater reuse with water efficient buildings, gardens and practices can produce "water independent households" throughout the region. This integrated water cycle management (IWCM) Option generated large reductions in demands for reticulated water supply (93.1% to 99%) with substantially diminished wastewater discharges (63% to 73%) and reductions in stormwater runoff (18% to 48%).
13. The internal water resources within North East Victoria that can be derived from water efficiency, rainwater, stormwater and wastewater are greater than the demands for urban water supplies.

Regional analysis

14. Adoption of water efficent buildings, gardens and practices in all new and redeveloped buildings throughout North East Victoria will provide reductions in water demands and wastewater discharges by 16.5% and 12.1% respectively in 2050.
15. Use of the RWH Option in all new and redeveloped buildings generates reductions in water demands (29.7%), wastewater discharges (12.1%) and stormwater runoff (18.6%) by 2050.
16. Use of the WWR Option for all new and redeveloped buildings creates reductions in water demands (24.2%) and wastewater discharges (26.7%) by 2050.
17. An IWCM Option for all new and redeveloped buildings generates reductions in water demands (45.6), wastewater discharges (35.7%) and stormwater runoff (19.3%) by 2050.
18. The IWCM Option will mitigate the "worst case" impacts of future climate change on urban water resources throughout the region and the remaining Options will siginficantly diminish the impacts of expected climate change.
19. More rapid rates of adoption for any of the Options will produce greater water resources benefits to the natural limits demonstrated by the lot scale results in items 9 to 12 above.

Strategies for Implementation, (Leadership and Community Engagement)

20. More rapid rates of adoption of alternative Options will produce greater water resources benefits to the natural limits demonstrated by the lot scale results in items 9 to 12 above.
21. Councils and all agencies can demonstrate community leadership by ensuring that all future projects include water security objectives in their decision making.
22. Councils in particular should ensure that this document does not become lost in the archives but continues to be a valuable source document informulating policies for building and development.
23. Councils should ensure that future Planning Schemes, particularly the Municipal Strategic Statements and Local Planning Policy Frameworks provide the catalyst for early adoption of the above findings.
24. Councils should develop engagement strategies to ensure that the findings of this report are implemented at the Lot Scale and across the wider community.
25. Councils, DPCD and North East Water should work together to ensure that the water security measures detailed in this report are considered in all future planning scheme rezoning, and major developments.

26. Strategies to encourage community acceptance, implementation and adoption will be required. This will require good leadership and governance, good community engagement and respected local champions.
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33. Strategies to encourage community acceptance, implementation and adoption will be required. This will require good leadership and governance, good community engagement and respected local champions.
34. North East Water should ensure that future Water Supply Demand Strategies are cognizant of the findings of this report and promote these water security measures.

Adoption of the above findings and recommendations should ensure that:

35. The right quality water is used for appropriate uses.
36. The community and agencies value their water resources.
37. That water conservation measures ensure that water is available for community assets and amenity, particularly in times of reduced rainfall.
38. Social amenity is maintained and enhanced.
39. The community understands the differences between water conservation and water restrictions.
40. The community recognises its unique position, high in the catchment, and is cognisant of both the quality and quantity of water available for downstream communities dependant on this resource.
41. findings of this report and promote these water security measures.

1 Introduction

The North East Greenhouse Alliance commissioned Dr. Peter Coombes and Bonacci Water to investigate options for improving water security and adapting to a low water future throughout the North East region.

This "Adapting to a Low Water Future" project is funded by the Australian Government's "Strengthening the Basin Communities" component of the "Water for the Future" program. The project is being delivered by the North East Greenhouse Alliance on behalf of the City of Wodonga, Rural City of Wangaratta and Alpine, Indigo, Towong Shires in partnership with the North East Catchment Management Authority, North East Water and Goulburn Murray Water.

The North East region of Victoria has one of the most secure water supplies in Victoria and the Murray Darling Basin. Major water storages include: Lake Dartmouth , Lake Hume, Lake Buffalo, Lake Mulwala and Lake William Hovell in addition to storages associated with the Kiewa Hydro Electric Scheme. The intent of this report is to determine how larger towns may use this valuable national resource more efficiently, and, to identify options and strategies for some smaller communities geographically separated from these major storages and the river flows they contribute to.

The North East region of Victoria makes a significant contribution to the available water resources in the Murray Darling Basin. Although the region only occupies 2% of the Murray Darling Basin, the rivers in the region provide over 38% of the water flows in the Basin.[1] Decreases in rainfall, increases in temperature and higher evaporation rates associated with the recent drought have highlighted the dependence of the region on reliable water resources. Long term reductions in available water resources that may eventuate from climate change will pose considerable challenges to business and the community within North East Victoria.

Alternative water management strategies have potential to supplement demands for water supplies, reduce sewage loads and to manage urban stormwater runoff. The benefits of alternative water cycle management strategies apply at different scales, to householders, various agencies and the environment. This study has investigated the detail of the systems benefits provided by alternative water cycle management strategies at 45 locations throughout the North East region of Victoria.

This report presents results ranging from the local household scale to regional scale that includes consideration of the water cycle management footprint of the region. The results from regional analysis of the impacts of water cycle management strategies on the performance of water and sewage distribution and headworks systems for North East Victoria, including regional economics and energy impacts, are presented in this report.

[1] North East CMA Annual Report 2009/10

2 Background

The natural water cycle is profoundly changed by urban development and the traditional hydraulic systems constructed to provide water services to settlements.[2] Typically, the area of impervious surfaces is increased in settlements, whilst natural watercourses are replaced with pipes and channels designed to be hydraulically efficient to expedite the removal of water to downstream receiving water bodies.

Australia's water supplies to cities have until recently been almost completely reliant on single sources of water derived from rainfall runoff collected from inland catchments. The future reliability of urban water systems dependent on single centralised sources of water is uncertain due to the combined pressures of population growth, a highly variable climate and the potential for climate change. Recent rainfall variability (from droughts to flooding rains) and the impacts of past decisions about infrastructure (such as the Desalination Plant and North South Pipeline) has driven renewed investigation of alternative approaches to achieve secure, resilient and flexible water services.

In addition, new and existing settlements that require water cycle services are increasingly remote from centralised services which compound declining natural resources with increasing infrastructure and conveyance costs. The ongoing sustainability of settlements is also further challenged by local and regional environmental impacts of traditional water infrastructure.

It is now recognised that multiple sources of water from centralised and decentralised locations in combination with a diverse range of water conservation strategies can increase the resilience and reliability of water supply to cities and towns.

Rather than continuing the centralised traditional paradigm there is a need to transform water planning into an integrated water cycle management paradigm. All water sources are valued as a resource and used at their source to reduce the demand on the centralised system and the cost of providing services. This involves providing water services in a more efficient and effective manner, maximising the use of water we have, retaining water in settlements and ensuring our towns remain liveable.

Climate change is expected to reduce average annual streamflows in the Upper Murray and Kiewa Rivers by up to 20% and the Ovens River by up to 25% in 2030. A combination of climate change and population growth will also increase demands for water.

In short, there is an urgent need to find a "better way" of providing water services, and this study investigates a range of alternative water strategies.

[2] Barton A, P.J. Coombes and J. Rodriguez, (2007). Understanding Ecological Response in Urban Catchments. Rainwater and Urban Design Conference. Engineers Australia. Sydney, Australia.

3 Options

In accordance with the objectives of the North East Greenhouse Alliance for North East Victoria, this study has focused on the opportunities to reduce mains water demands, sewerage discharges and impacts on waterways from urban development. It is a key objective to minimise the impacts of droughts, floods and climate change on the North East region whilst reducing impacts on dependent ecosystems and liveability.

A range of alternative Options have been examined for water cycle management throughout North East Victoria. The performance of each Option was compared to the performance of the Business as Usual (BAU) Option. The Options were established to test, compare and contrast a range of alternative futures.

The purpose of establishing Options is to enable testing of the physical, technical and commercial performance of the system without the influence of opinions, perceptions and agenda. Defining a base case (Business as Usual) and alternative Options enable the testing, comparison and understanding of the behaviour of the North East region.

It is important to note that this analysis has been constructed to understand the response of water cycle management throughout North East Victoria to a range of stressors and opportunities. This study does not endeavour to design the ultimate detail of solutions. This understanding will provide useful insight into systems behaviour that can inform decision making. The Options for water cycle management throughout North East Victoria examined in this study are discussed below.

3.1 Option 0 – Business as Usual (BAU)

Option 0 is the base case which assumes that centralised management of reticulated mains water supply, sewage disposal and stormwater runoff will be the dominant source of water cycle services to North East Victoria.

The BAU Option assumes that mains water will be supplied to most towns throughout the region from the existing headworks system that includes a network of rivers, dams and weirs within nine water supply districts.

It was also assumed that the BAU Option for towns without reticulated services includes water supply from rainwater tanks (capacity of 30 kL) and management of wastewater using septic tanks (capacity of 3 kL) and absorption trenches (240 m long, 0.45 m deep and 0.75 m wide).

This is not a viable option in the longer term. It is acknowledged that water storages on the larger rivers, and other strategies implemented by NEW, for example ground water bores at Wangaratta, have the capacity to provide for the critical human needs and water requirements for the major towns, albeit, under some water restriction regimes. Some of the smaller townships could be more vulnerable without the implementation of some of the strategies and options recommended in this report.

3.2 Option 1 – Water efficient appliances, gardens and practices (WEA)

This Option investigates the impacts of adopting water efficient buildings, gardens and practices throughout the region. The WEA strategy includes the use of water efficient toilets, clothes washers, shower heads and gardens. It is assumed that all new and renovated buildings throughout the region will include the equivalent of six star appliances as shown in Table 3.1.

Table 3.1: Characteristics of water efficient appliances in the WEA option

Appliances	Water use	Reduction (%)
Toilets	4.5/3 Litre flush	20
Taps	6 Litres/minute	50
Showers	7 Litres/minute	20
Clothes washers	80 Litres/wash	38
Outdoor	Low irrigation gardens	50

Table 3.1 shows that substantial water savings can be achieved using readily available products and approaches available to the industry. It is expected that the incorporation of water efficient gardens will be supported by Council planning policies, developer driven landscaping guidelines and education programs.

The WEA Option also incorporates programs to retrofit water efficiency into buildings in small rural towns that have limited access to reticulated water and sewage services.

Strategies to encourage community acceptance, implementation and adoption will be required. This will require good leadership and governance, good community engagement and respected local champions.

3.3 Option 2 – Rainwater harvesting (RWH)

Option 2 incorporates harvesting of rainwater from domestic roofs for toilet flushing, laundry uses and garden watering. The option employs 10,000 L (litre) rainwater tanks for detached housing and 5,000 L rainwater tanks for medium density dwellings.

It was also assumed that 30,000 L rainwater tanks would collect rainwater from roof areas of high density buildings to supply clusters of 10 dwellings. Each rainwater supply system will include a small first flush device (20 L) and a mains water bypass system for backup during period when water levels in tanks are low.

Rainwater tanks will be installed in all new and renovated houses in areas with traditional reticulated water services. This Option also includes the provision 20 kL additional rainwater storage for each dwelling in town that are not connected to traditional reticulated water supplies.

The author's investigations for these projects have established that use of rainwater in hot water services was a safe and efficient use of rainwater. The rainwater treatment train of a small first flush device, processes of settlement and flocculation in the rainwater storage, the cleansing processes of biofilms on the walls (slime) and on the bottom (sludge) of tanks, and heat death processes in the hot water services form a robust mechanism to deliver rainwater of acceptable quality for household consumption.[3,4]

[3] Spinks A.T., R.H. Dunstan, P.J. Coombes, T. Harrison, G. Kuczera, (2006). Heat Inactivation of Pathogenic Bacteria in Water at Sub-boiling Temperatures. Water Research. 40(6). 1326–1332.
[4] Coombes P.J., Hugh Dunstan, Anthony Spinks, Craig Evans and Tracy Harrison (2006). Key Messages from a Decade of Water Quality Research into Roof Collected Rainwater Supplies. 1st National HYDROPOLIS Conference, Perth, Western Australia

A variant of this Option (2.1) includes the use of rainwater for hot water supplies in towns connected to traditional reticulated water supplies.

3.4 Option 3 – Reuse of wastewater (WWR)

In Option 3 treated wastewater is supplied via a third pipe network for outdoor uses. There is an additional opportunity for wastewater reuse to support agri-business within or near towns. This Option examines augmentation or installation wastewater treatment plants at a strategic locations within town to provide treated effluent to greater than Class A+ standards.

Option 3 incorporates reuse of greywater from household showers and laundries for irrigation of gardens in towns without traditional water and wastewater services. This option is only used on conventional sized allotments which have sufficient area to the greywater to assimilate volumes.

3.5 Option 4 – Stormwater harvesting (SWH)

Option 4 includes stormwater harvesting for non-potable uses in towns connected to traditional reticulated water services. The provision of multiple smaller storages at a volume of 5 kL for each connected building that are closer to the source of stormwater runoff also optimises the requirement for storage.

Stormwater harvesting facilities are provided for all new and renovated developments for town connected to traditional reticulated water services. Towns without traditional reticulated water supplies include stormwater harvesting facilities for potable water supply that supplements existing water strategies.

3.6 Option 5 – Integrated water cycle management (IWCM)

Different combinations of Options 2 to 4 were analysed to develop ICWM strategies for towns throughout the region. This approach is similar to the strategies employed at the Aurora project by VicUrban, at the Pimpama Coomera Water Futures Strategy by Gold Coast City Council and in the Yarrabilba project by Delfin Lendlease.

Analysis of these types of projects that contain integrated infrastructure solutions reveal considerable additional infrastructure savings and benefits at the local scale that have only been partially considered in this study.[5] The significant opportunities imbedded in these types of integrated water cycle management Options are only revealed by detailed and integrated systems analysis of the entire water cycle. These opportunities are often, unfortunately, overlooked by the use of traditional assumptions and more simplistic analysis processes.

All new developments and redevelopments will form part IWCM strategies that will provide resilient water strategies. Rainfall is collected from roofs and used for laundry and hot water purposes. Wastewater is collected and treated at a localised scale to greater than class A standards using small scale modular wastewater treatment technology (such as Membrane Bioreactors). Treated wastewater is used for non-potable purposes such as toilet flushing, cooling, commercial processes and outdoor uses.

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[5] WBM (2005). Strategic stormwater study for the Pimpama Coomera Water Futures Strategy. Report for Gold Coast City Council with assistance from Dr. Peter Coombes.

The Option allows for provision of water cycle services that originate from resources generated within the towns including reduced demands created by more efficient buildings. The provision of multiple smaller storages that are closer to the source of stormwater runoff and generation of wastewater also optimises the requirement for storage. Similarly, the use of smaller wastewater catchments minimises the accumulation of stormwater and conveyance within sewage systems which also decreases the requirement for wastewater storages and treatment capacity.

A local IWCM strategy is established when development is of sufficient scale (such as Greenfield developments, substantial infill redevelopment, or a very large building or commercial complex). In situations where developments do not have sufficient scale (a single house, apartment block, commercial or industrial facility) the development will implement the individual elements of a precinct approach consistent with a “master plan” to enable integration into a Precinct at a later stage.

New developments also have access to traditional reticulated water and wastewater services. The reliance on these services may be significantly diminished from the BAU option as determined by climate and demographic variables.

4 Scenarios

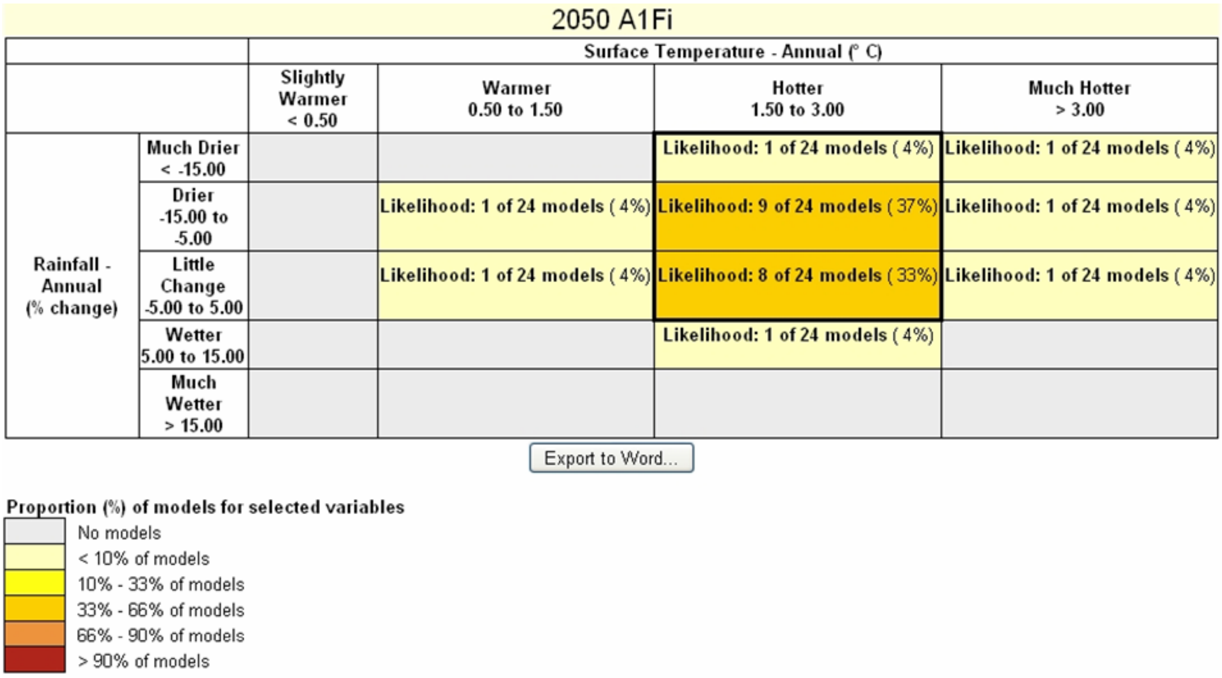
A range of scenarios were established to test the response of the Options to foreseeable future threats and opportunities. The Scenarios applied to each of the Options for water cycle management throughout North East Victoria examined in this study are discussed in Table 4.1.

Table 4.1: Summary of Scenarios

Scenario	Description
Low Emissions Climate Change (LE)	The lower bounds of IPCC/CSIRO Climate Change projections of a (0.025°C) incremental change in average maximum temperature.
High Emissions Climate Change (HE)	Upper bounds of IPCC/CSIRO Climate Change projections of a (0.05°C) incremental change average maximum in temperature.
Low Population Growth (0%)	Annual average population growth remaining static (0%) across North East Victoria from 2011 to 2050.
High Population Growth (2%)	Annual average population growth of 2% across North East Victoria from 2011 to 2050.
Economic Structural Change (EC)	Structural change in the economy results from a change in agricultural activity in the region. This results in reduced commercial and industrial water demand.
Reduced water allocations (40%)	Water allocations throughout the Murray Darling Basin are reduced by 40%.

4.1 Scenarios 1 and 2: Climate Change

Scenarios 1 and 2 represent the lower and upper bounds of the current high emissions scenario from the Intergovernmental Panel on Climate Change (IPCC). A summary of the latest results from the IPCC models provided by the Bureau of Meteorology (BOM) for 2050 is presented in Figure 4.1.



2050 A1Fi

		Surface Temperature - Annual (° C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Rainfall - Annual (% change)	Much Drier < -15.00			Likelihood: 1 of 24 models (4%)	Likelihood: 1 of 24 models (4%)
	Drier -15.00 to -5.00		Likelihood: 1 of 24 models (4%)	Likelihood: 9 of 24 models (37%)	Likelihood: 1 of 24 models (4%)
	Little Change -5.00 to 5.00		Likelihood: 1 of 24 models (4%)	Likelihood: 8 of 24 models (33%)	Likelihood: 1 of 24 models (4%)
	Wetter 5.00 to 15.00			Likelihood: 1 of 24 models (4%)	
	Much Wetter > 15.00				

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Proportion (%) of models for selected variables
- No models
- < 10% of models
- 10% - 33% of models
- 33% - 66% of models
- 66% - 90% of models
- > 90% of models

Figure 4.1: A summary of climate models from the IPCC analysis of the high emissions assumptions

Figure 4.1 shows that the majority of global climate models predict increase in average temperatures ranging from 1.5°C to 3°C for the region. Similarly it appears to be equally likely for little change in rainfall and dryer rainfall conditions. The previous estimates of the impacts of climate change by the Department of Sustainability and Environment (DSE) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) are presented in Table 4.1.[6]

Table 4.1: Summary of the impacts of climate change for North East Victoria

Criteria	2030	2070	
		Low	High
Change in average temperature (°C)	0.6 to 1.2	1.0 to 2.1	2.0 to 4.0
Change in annual rainfall (%)	-9 to +2	-14 to +2	-25 to +5
Change in potential evaporation (%)	+1 to +5	+2 to +8	+4 to +16
Change in annual stream flow (%)	-20 to -25	-5 to -50	-5 to -50

Table 4.1 shows that previous estimates of climate change in the North East of Victoria predicted large changes in average temperatures and potential evaporation with moderate changes in rainfall. In accordance with the latest IPCC summary (Figure 4.1) the low emissions scenario (LE) was analysed as a 0.025°C incremental change in average maximum temperature and the high emissions scenario was analysed as 0.05°C incremental change average maximum in temperature.

[6] DSE (2008). Climate change in the North East region. Department of Sustainability and Environment.

4.2 Scenario 3: Low Population Growth (0%)

Scenario 3 is characterised by lower than expected population growth that remains static (0% annual average growth) from 2011 to 2050.

4.3 Scenario 4: High Population Growth (2%)

Scenario 4 is characterised by higher than expected average annual population growth of 2% from 2011to 2050.

4.4 Scenario 5: Economic Structural Change (EC)

Scenario 5 represents structural change in the economy of the North East region resulting in reduced Commercial and industrial water demand. Reduction in agricultural activity throughout the region will have significant impact in the economies of towns throughout the region.

4.5 Scenario 6: Reductions in water allocations (WA)

Scenario 6 represents a 40% reduction in water allocations throughout the Murray Darling Basin.

5 Methods

This study employed an integrated systems approach to analysing the performance of integrated water cycle management Options for North East Victoria. The Options were determined to generate understanding of the response of the water cycle systems throughout North East Victoria to alternative strategies. This unique analysis is dependent on detailed inputs, such as demographic profiles, and linked systems that accounts for water supply, sewerage, stormwater and environmental considerations. This section outlines the key assumptions and methods used in this analysis.

In addition, a parallel investigation was undertaken to understand the opinions and experience of stakeholders throughout the region. Stakeholders provided analysis of many aspects of the North East region from multiple perspectives, input to the systems analysis, review and interpretation of systems outcomes, and input to the final report.

It is important construct the systems analysis from the basic elements (the lot scale inputs) that drive system behaviours and account for first principles transactions within the system to allow simulation of spatial performance of the system. Biophysical systems in the North East region were constructed using three basic components:

- Sources - Regional and local water sources, catchments and waterways
- Flux – transport and treatment of water, sewage and stormwater throughout the region
- Sinks – Stormwater runoff and wastewater disposal to waterways

This fundamental concept is outlined in Figure 5.1.

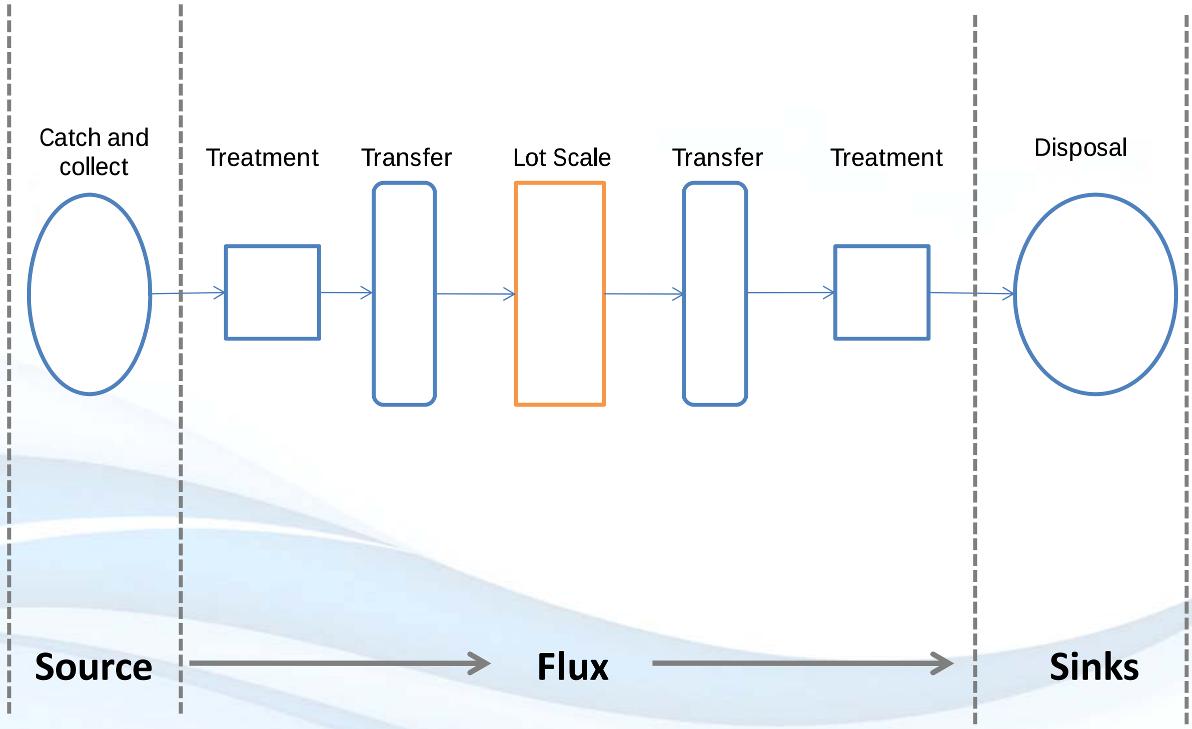

Figure 5.1: The principles underpinning any water system – Sources, Fluxes and Sinks

Figure 5.1 shows that the foundation principles used as the basis of the systems analysis in this project – the system is driven by demands at the lot scale (including water, sewage, stormwater and environmental demands or discharges) that require movement of water (Fluxes) from a range of sources and disposal of water (such as sewage and stormwater) to a range of sinks.

The framework for analysis of the North East Victorian system was compiled from the lot scale to regional scale is presented in Figure 5.2.

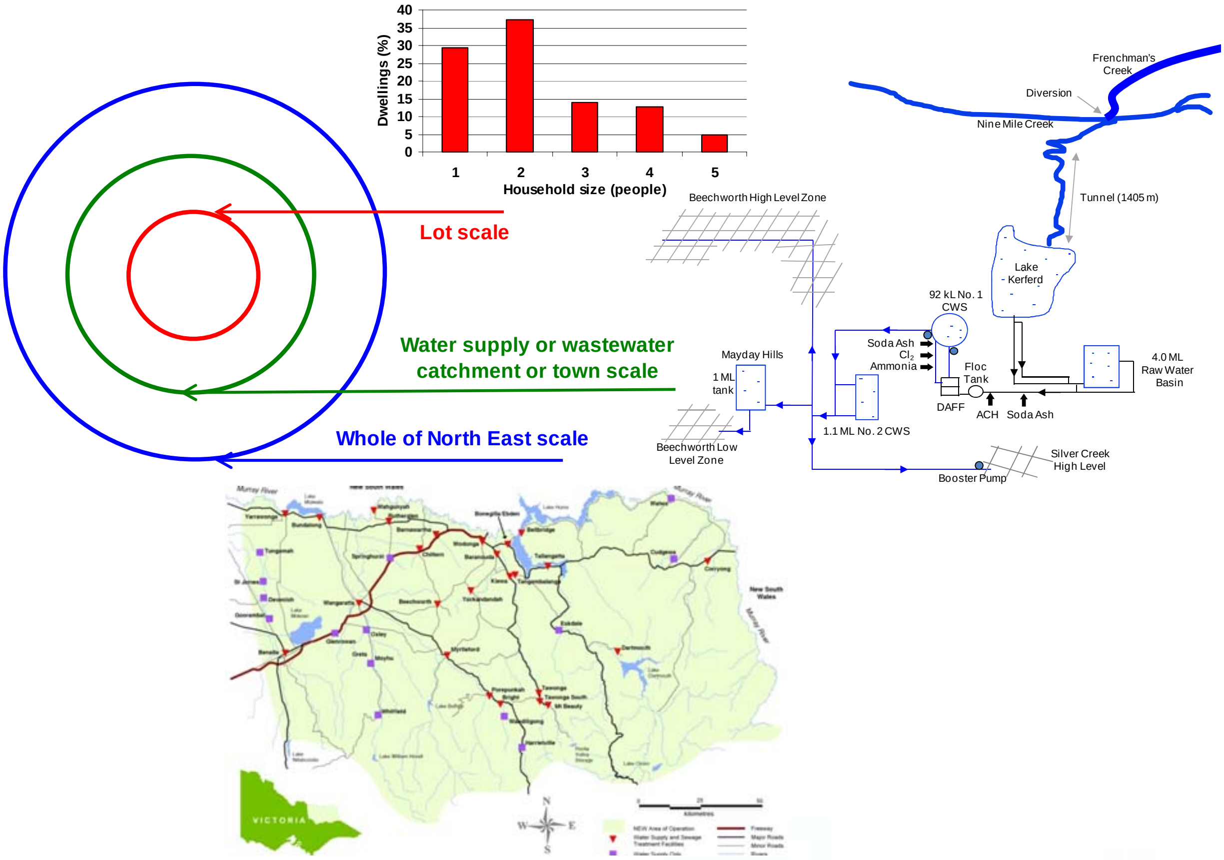

Figure 5.2: Three linked spatial scales used in the analysis and in calibration

Figure 5.2 highlights the elements that were incorporated at different scales in the analysis. This includes water use and demographics at the lot scale, distribution infrastructure and information at the sub-regional or town scale, and regional behaviours or infrastructure such as water extractions from and discharges of sewage to the North Head wastewater treatment plant. This process can be described as analysis of systems within systems across multiple scales. Our unique biophysical and scale transition framework links the dynamics of the systems with inputs across scales and time.

The analysis is anchored by a regional framework of key trunk infrastructure, demand nodes, discharge points, waterways and regional sources of water in the WATHNET systems model. Major water distribution, stormwater, sewage, demographic, climate and topographic zones are combined in this framework. This process compiles inputs from a wide range of commonly utilised analysis tools, including for local water demands and water balances (such as PURRS) and hydrology. Key simulation inputs to this framework include:

- Demographic data from the Australia Bureau of Statistics and State Government departments
- Climate data from the Bureau of Meteorology and streamflow data from the Victorian Data Warehouse
- Water and sewage flows sourced from North East Water
- Local and cluster scale inputs simulated in the PURRS model at 6 minute timesteps using long climate records.
- Urban areas and small rural towns analysed using a range of models including PURRS and MUSIC. These smaller scale systems are also analysed in more detailed WATHNET models.
- The biophysical and scale transition model compiles inputs from PURRS into the zones based on statistical local areas and calibrates to observed data from water and sewage catchments.
- The Wathnet model was used to collate and simulate all inputs across the entire region

This framework incorporates the movement of water throughout the region and connectivity to the water supply headworks system. Similarly, this framework includes the movement of sewage throughout the region and connectivity with discharge points or reuse systems. It includes stormwater catchments, conveyance systems and urban streams as shown in Figure 5.3.

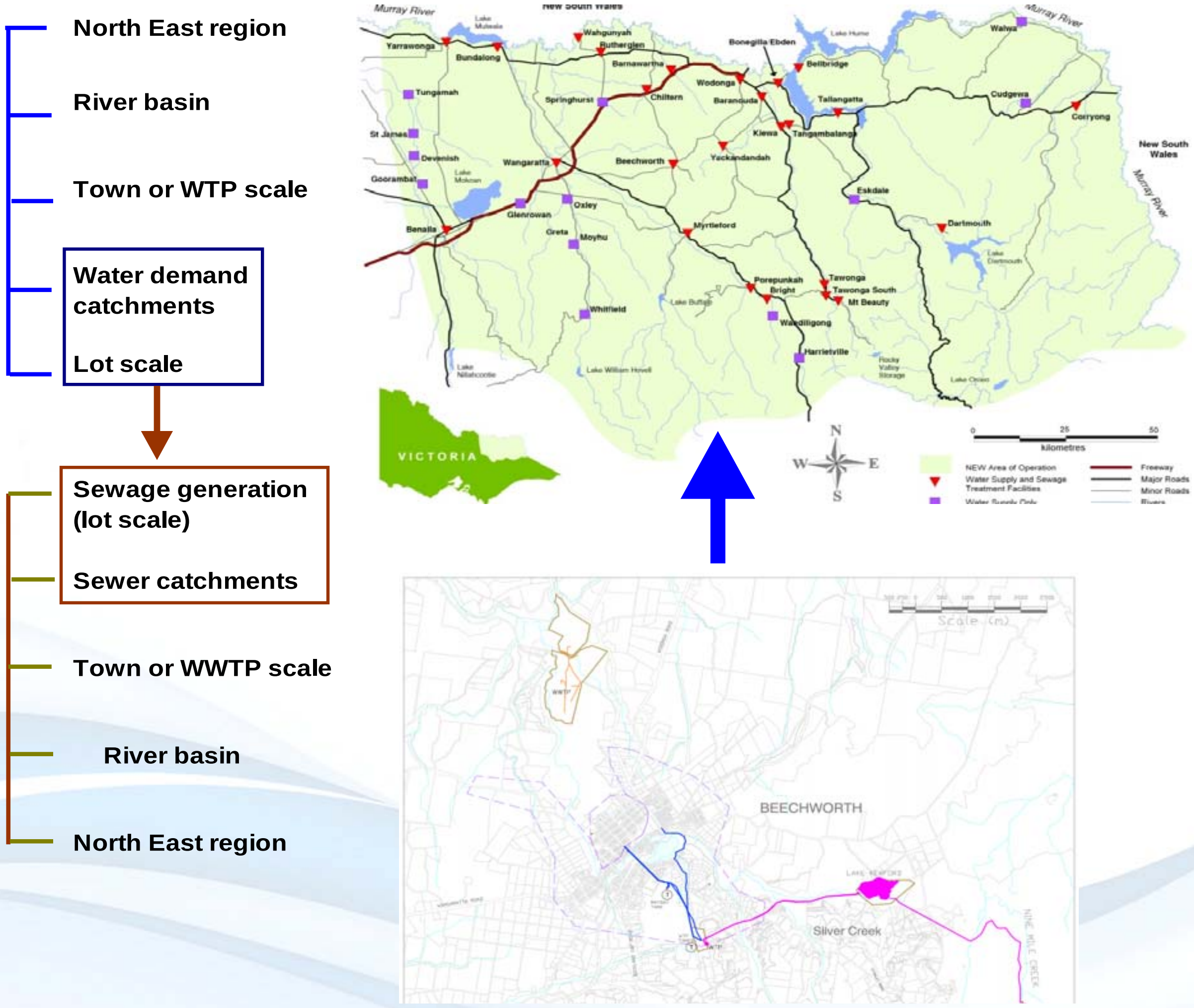

Figure 5.3: The linked nature of water and wastewater systems employed in this analysis

Importantly, the framework shown in Figure 5.3 is driven by long sequences of spatially consistent input data that captures the spatial and temporal variation in climate (rainfall, temperature and frequency of rainfall), demographics, water demands and water management strategies across the North East region. This ensures that the impact of the considerable spatial variation and connectivity across the region is robustly incorporated in the framework leading to accurate understanding of internal and external augmentation requirements. Clearly the region does not respond "on average" and this process captures the dynamics of feedback loops from sources to sinks throughout the region.

For example, this framework provides comprehensive systems understanding of the dynamics of sewage discharges, including interaction with stormwater systems, to sewage treatment plants and the impact of reusing treated effluent from the contributing sewage catchments. It will allow an understanding for the changes in sewage flows, demands for recycled water and requirement for reuse infrastructure throughout North East Victoria with the consequent changes in distribution of water from external sources (such as rivers and groundwater) throughout the region. This allows understanding of the changed energy profiles, the extent of reuse required and the operating costs of any strategy. In addition, this connectivity allows understanding of the regional water security and resilience to climate change provided by an alternative Options – a proportion of North East Victoria's water security will be provided by internal sources.

Wherever possible the analysis incorporates first principles information and sequences of inputs rather than averages. Smaller scale inputs to the regional framework involve more detailed analysis of selected towns, commercial, industrial and agricultural areas. This analysis includes the dynamic inputs of local infrastructure and building form to the regional framework.

Details of the analysis, extractions from the data and modelling process have been provided throughout this Section to assist with understanding the systems processes used in this study. Household water consumption for the period 2005 to 2006 was selected in this study as the representing base water consumption for the region during a period relatively free of water restrictions. These water demands were then modified by a range of processes including adoption of water efficient appliances in some houses, connection to wastewater reuse systems and changes in demographics (see Section 5.6). The year used for the economic analysis is the 2009/10 financial period.

5.1 Selection of zones

The North East region has been divided into 45 zones for regional analysis (see Figure 5.4) using the following data:

- Boundaries, demographics and socio-economics from ABS "State Suburbs" and "Statistical Local Areas".
- River basins
- Local government boundaries
- Water and sewage districts from NERWA
- Climate data from the BOM

The zones presented in Figure 5.4 are also described in Table 5.1.

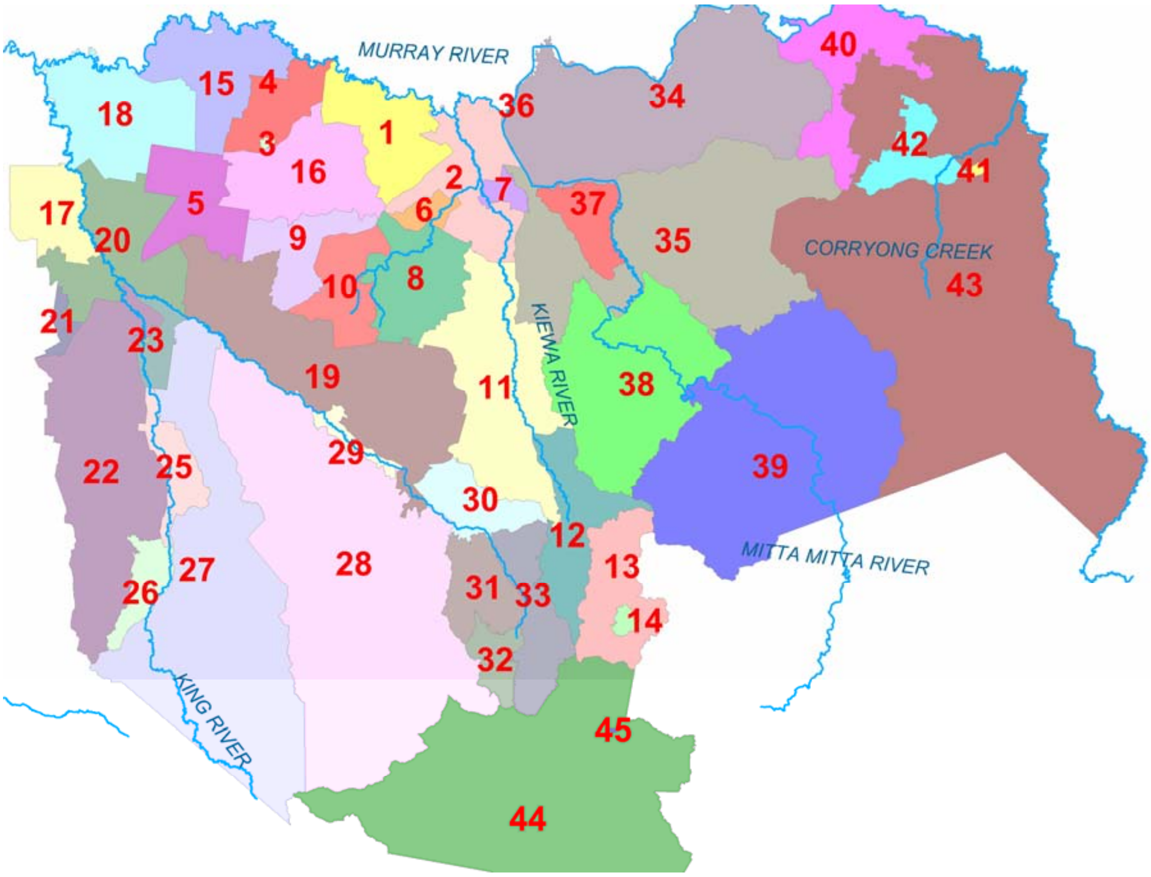

Figure 5.4: Zones used to analyse water cycle management in the North East region

Table 5.1: Description of zones used in the analysis

Zone	Number	Zone	Number	Zone	Number
Wodonga City	1	Indigo Valley	16	Wandiligong	31
Wodonga East	2	Killawarra	17	Harrietville	32
Chiltern	3	Ovens Murray	18	Freeburgh	33
Barnawartha	4	Ovens North	19	Hume East	34
Springhurst	5	Wangaratta	20	Hume South	35
Staghorn Flat	6	Glenrowan	21	Bellbridge	36
Huon	7	King West	22	Tallangatta	37
Yackandandah	8	Oxley	23	Eskdale	38
Beechworth	9	Milawa	24	Dartmouth	39
Stanley	10	Moyhu	25	Walwa	40
Middle Kiewa	11	Whitfield	26	Corryong	41
Mount Beauty	12	King East	27	Cudgewa	42
Bogong	13	Ovens South	28	Upper Murray	43
Falls Creek	14	Myrtleford	29	Hotham Heights	44
Rutherglen	15	Bright	30	Dinner Plain	45

Water use and demographic considerations

A combination of average household water use, demographic and climate data was utilised to develop water use profiles for a variety of household sizes (one to five people) and types (detached, semi detached and units) in each zone. Long daily records of temperature and rainfall at each location were combined with pluviograph (6 minute) rainfall records to create synthetic pluviograph records of suitable length for robust simulation of Options in the PURRS (Probabilistic Urban Rainwater and wastewater Reuse Simulator) model. A diurnal pattern was employed to disaggregate household water use into sub-daily time steps. The use of long climate records and sub-daily time steps was required for reliable simulation of rainwater and stormwater harvesting scenarios.

The sequences of water use and sewage discharges for each location were calibrated using the selected climate information in the PURRS model and water use records from North East Water. A range of scenarios was simulated using PURRS that account for different household sizes, types of dwellings and alternative water management strategies. These results are used to determine responses to a range of drivers including alternative strategies, impacts on stormwater, sewage and mains water systems, and economics at each location.

Annual water use data was provided for the water districts throughout North East Victoria by North East Water. However, the usefulness of this data for understanding household water use behaviour is limited because this data is derived from rolling quarterly metering programs with variable periods and each area has different demographic and socioeconomic components. Annual water use measurements from commercial, industrial and other sectors provided by North East Water was also utilised in this analysis.

The Australian Bureau of Statistics (ABS) provides information about household size and distribution of dwelling types for each zone. This data provides an opportunity to unlock the characteristics of water use for each household type and for various household sizes within a given area.

5.2 Climate

The performance of alternative water use strategies is primarily dependent on climate processes at a given location. Water demands are also influenced by the local climate variables rainfall and temperature which are subject to considerable temporal and spatial variation across the region. This Section presents the spatial variation of climate processes across the North East Victoria.

Selection of rainfall and temperature Records

Reliable analysis of the performance of alternative water systems is dependent on the use of realistic water demand and local rainfall sequences. The physical processes involved in rainwater and stormwater harvesting including collection of roof runoff and rainwater supply to households can only be accurately simulated using sub-daily time steps and the longest available rainfall records.

Daily rainfall and temperature records containing greater than 30 years of data that also include the recent drought were obtained from the Bureau of Meteorology for locations throughout North East Victoria. In addition, pluviograph (6 minute) rainfall records containing greater than 10 years of data were obtained from the Bureau of meteorology for the region. More than 72 daily rainfall and 35 pluviograph records were identified and some of these records were used to derive long synthetic pluviograph records at each location.

Development of long term pluviograph rainfall records

Synthetic pluviograph (6 minute) rainfall records were derived at locations with long daily rainfall records using a non-parametric nearest neighbourhood scheme.[7] At a given site with a daily rainfall record, data from pluviograph rainfall records with different time periods in surrounding areas can be utilised to disaggregate daily rainfall into a synthetic pluviograph rainfall record. A diagram of the concept is shown in Figure 5.5.

The non-parametric scheme utilises climate and seasonal parameters (daily rainfall depth, month, count of days since last rain event) at the daily rainfall and nearby pluviograph rainfall sites to select a day of pluviograph rainfall from the most appropriate nearby pluviograph record. For each day in the daily rainfall record a day of pluviograph rainfall record is chosen using climate and seasonal parameters, and a ranking scheme. The nearby pluviograph records can be ranked on the basis of proximity to the location of the daily rainfall record and similarity of annual rainfall depths, topography and distance from the coast. This allows disaggregation of the daily rainfall records into a series of storm events and dry periods that constitute a continuous synthetic pluviograph rainfall record.

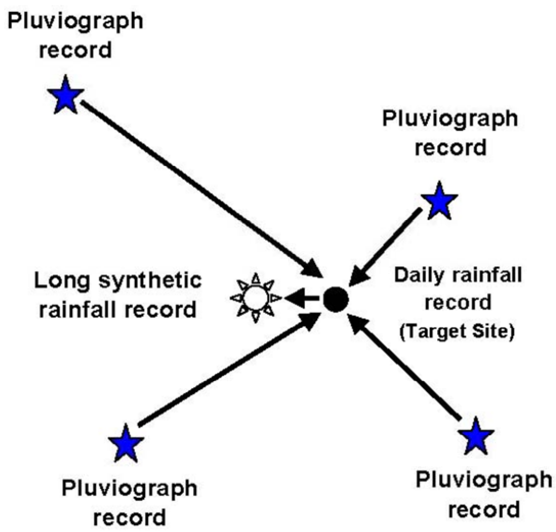

Figure 5.5: Diagram of the non-parametric nearest neighbourhood scheme for development of synthetic pluviograph records

This process ensures that the synthetic continuous rainfall record will have similar rainfall patterns to the chosen site whilst the total daily rainfall depths in the synthetic rainfall record are conditioned on the daily rainfall record. In the non-parametric nearest neighbourhood scheme a rank is used to prioritise the search process for a continuous rainfall pattern that best matches the climate characteristics of the daily rainfall record on any given day.

[7] Coombes P.J., 2004. Development of Synthetic Pluviograph Rainfall Using a Non-parametric Nearest Neighbourhood Scheme. WSUD2004 conference. Adelaide.

Example from the Wodonga zone

A synthetic pluviograph rainfall record with a length of 116 years and average annual rainfall depth of 711 mm was constructed for the Wodonga area using daily rainfall from Wodonga with pluviograph rainfall from Hume, Rutherglen, Ovens River and Wangaratta. These pluviograph records were chosen as the closest available long records to the site and to account for the spatial influence of weather events on the area.

Rainfall

Average annual rainfall at each of the zones used in this study is presented in Figure 5.6 to highlight the spatial distribution of rainfall throughout the region.

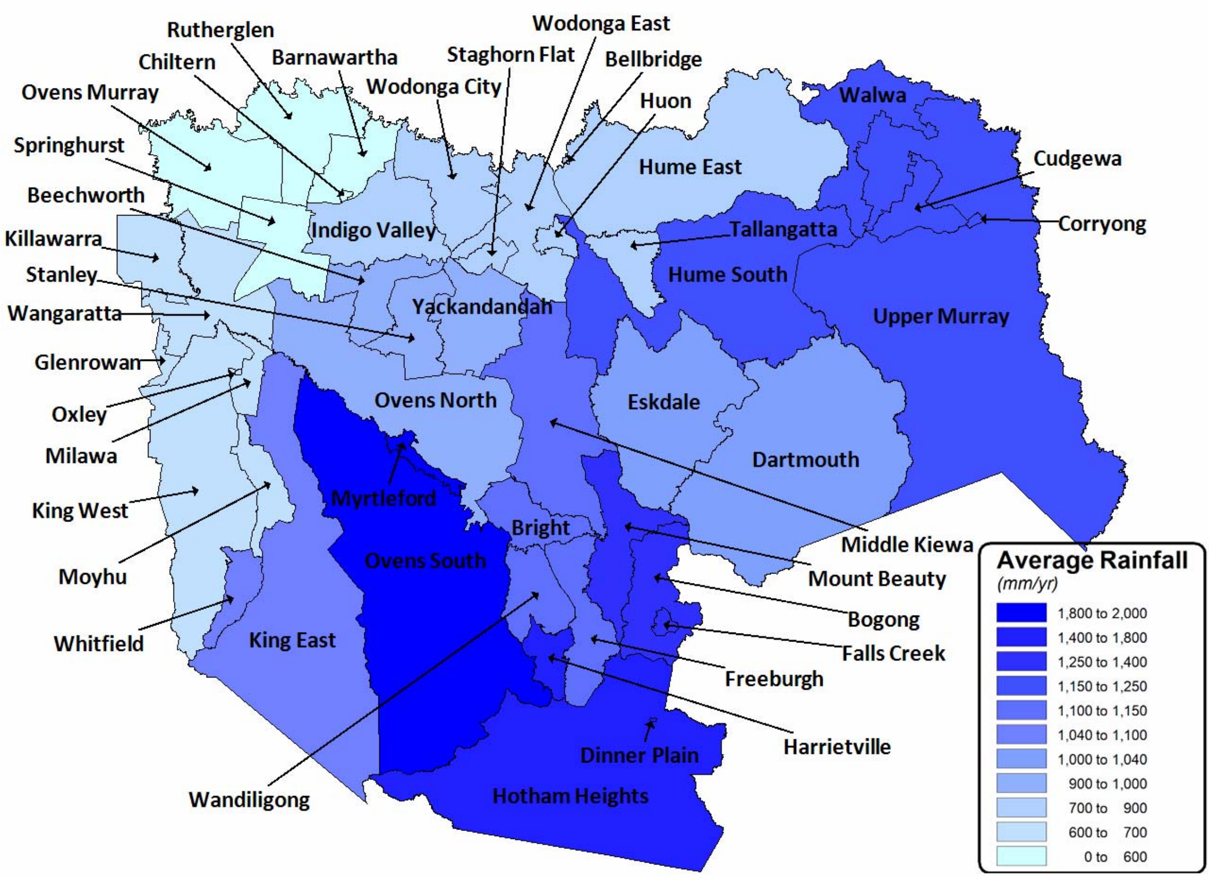

Figure 5.6. Spatial distribution of average annual rainfall across the North East Victoria

Figure 5.6 shows considerable variation in average annual rainfall across the region with the highest rainfall of 1,818 mm experienced at Bright and Ovens South zones with the lowest rainfall of 582 mm occurring in the Killawarra and Ovens Murray zones. Use of the actual rainfall records at each location throughout the North East Victoria will provide a more reliable analysis of alternatives strategies and generate more robust water demand profiles.

The daily rainfall observations from the Bureau of Meteorology (BOM) used to derived rainfall records for each LGA are shown in Table 5.3 and the pluviograph records used to create continuous rainfall records are presented in Table 5.4.

Table 5.3: Rainfall records used for each zone in the North East region

LGA	BOM Station(s) used	Start (Year)	End (Year)	Length (years)	Rainfall (mm/yr)
Barnawartha	Chiltern (82010)	1/01/1986	31/12/2010	125	690
Beechworth	Beechworth (82001)	1/01/1880	31/12/2010	131	996
Bellbridge	Hume Reservoir (72023)	1/01/1922	31/12/2010	89	694
Bogong	Harrietville (83012)	1/01/1904	31/12/2010	107	1402
Bright	Mount Buffalo (83073)	1/01/1911	31/12/2010	100	1818
Chiltern	Chiltern (82010)	1/01/1886	31/12/2010	125	690
Corryong	Nariel Creek (82035)	1/01/1885	31/12/2010	124	1038
Cudgewa	Nariel Creek (82035)	1/01/1885	31/12/2010	124	1038
Dartmouth	Callaghan Creek (82008)	1/01/1912	31/12/2010	99	1020
Dinner Plain	Omeo Shannon Vale (83035)	1/01/1958	31/12/2010	52	901
Eskdale	Callaghan Creek (82008)	1/01/1912	31/12/2010	99	1020
Falls Creek	Omeo Shannon Vale (83035)	1/01/1958	31/12/2010	52	901
Freeburgh	Harrietville (83012)	1/01/1904	31/12/2010	107	1402
Glenrowan	Milawa Brown Bros (82029)	1/01/1903	31/12/2010	108	653
Harrietville	Harrietville (83012)	1/01/1904	31/12/2010	107	1402
Hotham Heights	Omeo Shannon Vale (83035)	1/01/1958	31/12/2010	52	901
Hume East	Tallangatta DCNR (82045)	1/01/1901	31/12/2010	110	813
Hume South	Tallangatta DCNR (82045)	1/01/1901	31/12/2010	110	813
Huon	Tangambalanga (82046)	1/01/1895	31/12/2010	116	773
Indigo Valley	Yackandandah (82058)	1/01/1897	31/12/2010	114	946
Killawarra	Boorhaman (82006)	1/01/1909	31/12/2010	102	582
King East	Carboor (82009)	1/01/1911	31/12/2010	100	915
King West	Milawa Brown Bros (82029)	1/01/1903	31/12/2010	108	653
Middle Kiewa	Kergunyah South (82022)	1/01/1887	31/12/2010	124	909
Milawa	Milawa Brown Bros (82029)	1/01/1903	31/12/2010	108	653
Mount Beauty	Harrietville (83012)	1/01/1904	31/12/2010	107	1402
Moyhu	Milawa Brown Bros (82029)	1/01/1903	31/12/2010	108	653
Myrtleford	Carboor (82009)	1/01/1911	31/12/2010	100	915
Ovens Murray	Boorhaman (82006)	1/01/1909	31/12/2010	102	582
Ovens North	Beechworth (82001)	1/01/1880	31/12/2010	131	996
Ovens South	Mount Buffalo (83073)	1/01/1911	31/12/2010	131	1818
Oxley	Milawa Brown Bros (82029)	1/01/1903	31/12/2010	108	653
Rutherglen	Springhurst (82041)	1/01/1901	31/12/2010	110	606
Springhurst	Springhurst (82041)	1/01/1901	31/12/2010	110	606
Staghorn Flat	Tangambalanga (82046)	1/01/1895	31/12/2010	116	773
Stanley	Beechworth (82001)	1/01/1880	31/12/2010	131	996
Tallangatta	Tallangatta DCNR (82045)	1/01/1901	31/12/2010	110	813
Upper Murray	Walwa (82052)	1/01/1895	31/12/2010	116	818
Walwa	Walwa (82052)	1/01/1895	31/12/2010	116	818
Wandiligong	Harrietville (83012)	1/01/1904	31/12/2010	107	1402
Wangaratta	Milawa Brown Bros (82029)	1/01/1903	31/12/2010	108	653
Whitfield	Whitfield (83031)	1/01/1904	31/12/2010	107	1096
Wodonga City	Wodonga (82056)	1/01/1899	31/12/2010	116	711
Wodonga East	Tangambalanga (82046)	1/01/1895	31/12/2010	116	773
Yackandandah	Yackandandah (82058)	1/01/1897	31/12/2010	114	946

Table 5.4: Pluviograph rainfall records used to derive continuous rainfall for each zone

LGA	Pluviograph Site 1	Pluviograph Site 2	Pluviograph Site 3	Pluviograph Site 4
Barnawartha	Rutherglen (82039)	Hume (72023)	Ovens River (82121)	Wangaratta (82138)
Beechworth	Ovens River (82121)	Rutherglen (82039)	Wangaratta (82138)	Hume (72023)
Bellbridge	Hume (72023)	Rutherglen (82039)	Dartmouth (82076)	Ovens River (82121)
Bogong	Bright (83067)	Dartmouth (82076)	Omeo (83025)	Benambra (83003)
Bright	Bright (83067)	Edi Upper (83083)	Whitfield (83031)	Dartmouth (82076)
Chiltern	Rutherglen (82039)	Ovens River (82121)	Hume (72023)	Wangaratta (82138)
Corryong	Corryong (82011)	Khancoban (72060)	Tooma (72163)	Valentines (72112)
Cudgewa	Corryong (82011)	Khancoban (72060)	Dartmouth (82076)	Tooma (72163)
Dartmouth	Dartmouth (82076)	Benambra (83003)	Corryong (82011)	Bright (83067)
Dinner Plain	Omeo (83025)	Bright (83067)	Crooked River (84125)	Benambra (83003)
Eskdale	Dartmouth (82076)	Bright (83067)	Hume (72023)	Corryong (82011)
Falls Creek	Bright (83067)	Omeo (83025)	Dartmouth (82076)	Benambra (83003)
Freeburgh	Bright (83067)	Dartmouth (82076)	Edi Upper (83083)	Whitfield (83031)
Glenrowan	Wangaratta (82138)	Ovens River (82121)	Whitfield (83031)	Edi Upper (83083)
Harrietville	Bright (83067)	Omeo (83025)	Crooked River (84125)	Dartmouth (82076)
Hotham Heights	Omeo (83025)	Bright (83067)	Crooked River (84125)	Benambra (83003)
Hume East	Hume(72023)	Dartmouth (82076)	Corryong (82011)	Rutherglen (82039)
Hume South	Hume (72023)	Dartmouth (82076)	Bright (83067)	Corryong (82011)
Huon	Hume (72023)	Rutherglen (82039)	Dartmouth (82076)	Bright (83067)
Indigo Valley	Rutherglen (82039)	Hume (72023)	Ovens River (82121)	Wangaratta (82138)
Killawarra	Ovens River (82121)	Wangaratta (82138)	Rutherglen (82039)	Dookie (81013)
King East	Edi Upper (83083)	Whitfield (83031)	Rutherglen (82039)	W Hovell Res (83074)
King West	Whitfield (83031)	Wangaratta (82138)	Edi Upper (83083)	Ovens River (82121)
Middle Kiewa	Bright (83067)	Hume (72023)	Dartmouth (82076)	Edi Upper (83083)
Milawa	Wangaratta (82138)	Ovens River (82121)	Edi Upper (83083)	Whitfield (83031)
Mount Beauty	Bright (83067)	Dartmouth (82076)	Omeo (83025)	Benambra (83003)
Moyhu	Wangaratta (82138)	Whitfield (83031)	Edi Upper (83083)	Ovens River (82121)
Myrtleford	Bright (83067)	EDI UPPER (83083)	Whitfield (83031)	Wangaratta (82138)
Ovens Murray	Rutherglen (82039)	Ovens River (82121)	Wangaratta (82138)	Dookie (81013)
Ovens North	Ovens River (82121)	Wangaratta (82138)	Edi Upper (83083)	Bright (83067)
Ovens South	Bright (83067)	Edi Upper (83083)	Whitfield (83031)	W Hovell Res (83074)
Oxley	Wangaratta (82138)	Ovens River (82121)	Edi Upper (83083)	Whitfield (83031)
Rutherglen	Rutherglen (82039)	Ovens River (82121)	Wangaratta (82138)	Hume (72023)
Springhurst	Rutherglen (82039)	Ovens River (82121)	Wangaratta (82138)	Hume (72023)
Staghorn Flat	Hume (72023)	Rutherglen (82039)	Ovens River (82121)	Bright (83067)
Stanley	Ovens River (82121)	Rutherglen (82039)	Wangaratta (82138)	Bright (83067)
Tallangatta	Hume (72023)	Dartmouth (82076)	Bright (83067)	Rutherglen (82039)
Upper Murray	Corryong (82011)	Khancoban (72060)	Tooma (Eudlo) (72163)	Tooma (72099)
Walwa	Corryong (82011)	Tooma (Eudlo) (72163)	Tooma (72099)	Khancoban (72060)
Wandiligong	Bright (83067)	Edi Upper (83083)	Whitfield (83031)	Dartmouth (82076)
Wangaratta	Ovens River (82121)	Wangaratta (82138)	Rutherglen (82039)	Edi Upper (83083)
Whitfield	Whitfield (83031)	Edi Upper (83083)	W Hovell Res (83074)	Lima South (82107)
Wodonga City	Hume (72023)	Rutherglen (82039)	Ovens River (82121)	Wangaratta (82138)
Wodonga East	Hume (72023)	Rutherglen (82039)	Ovens River (82121)	Bright (83067)
Yackandandah	Hume (72023)	Rutherglen (82039)	Ovens River (82121)	Bright (83067)

Seasonal distribution of rainfall

The seasonal distribution of rainfall at selected locations is presented in Figure 5.7.

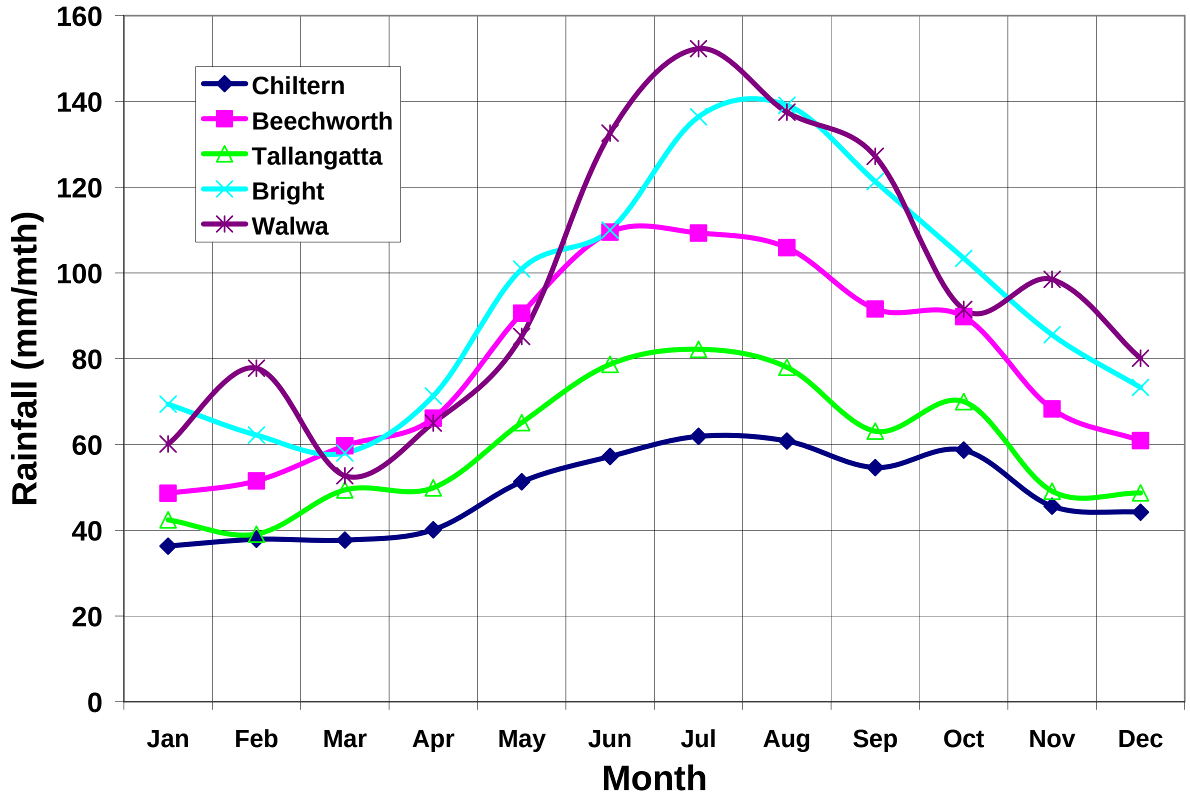

Figure 5.7: Mean monthly rainfall at selected locations across North East Victoria

Figure 5.7 reveals that the region is subject to higher rainfall during the Winter. The dominance of Winter rainfall in the seasonal distribution is more significant in areas with higher rainfall and elevations such as Walwa, Bright and Beechworth.

Average annual rain days

The frequency of rain events is an important indicator of water demands and the potential of strategies that include rainwater and stormwater harvesting. Average annual number of days with rainfall at each of the zones used in this study is shown in Figure 5.8.

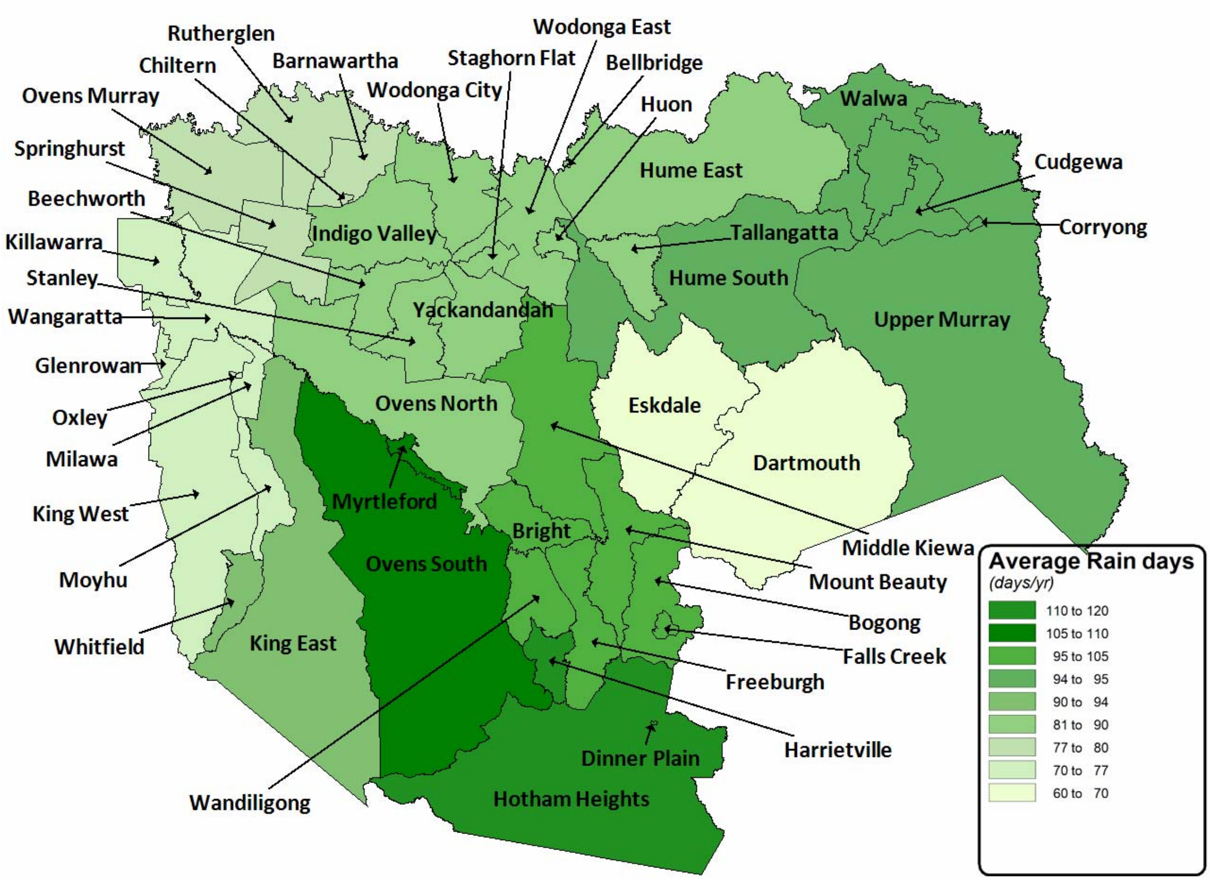

Figure 5.8: Spatial distribution of the frequency of rainfall across North East Victoria

Figure 5.8 shows considerable variation in the frequency of rainfall across the region with the highest number of annual rain days (110) occurring at Harrietville, Hotham Heights and Dinner Plains with the lowest number of rain days (61) occurring at Eskdale and Dartmouth.

A majority of the region is subject to relatively high number of average annual rain days with only a small proportion of the region experiencing less than 70 average annual rain days. The frequency of rain days across North East Victoria ranges from rainfall occurring, on average, every 3 to 6 days. The seasonal variation in the frequency of rainfall is presented in Figure 5.9.

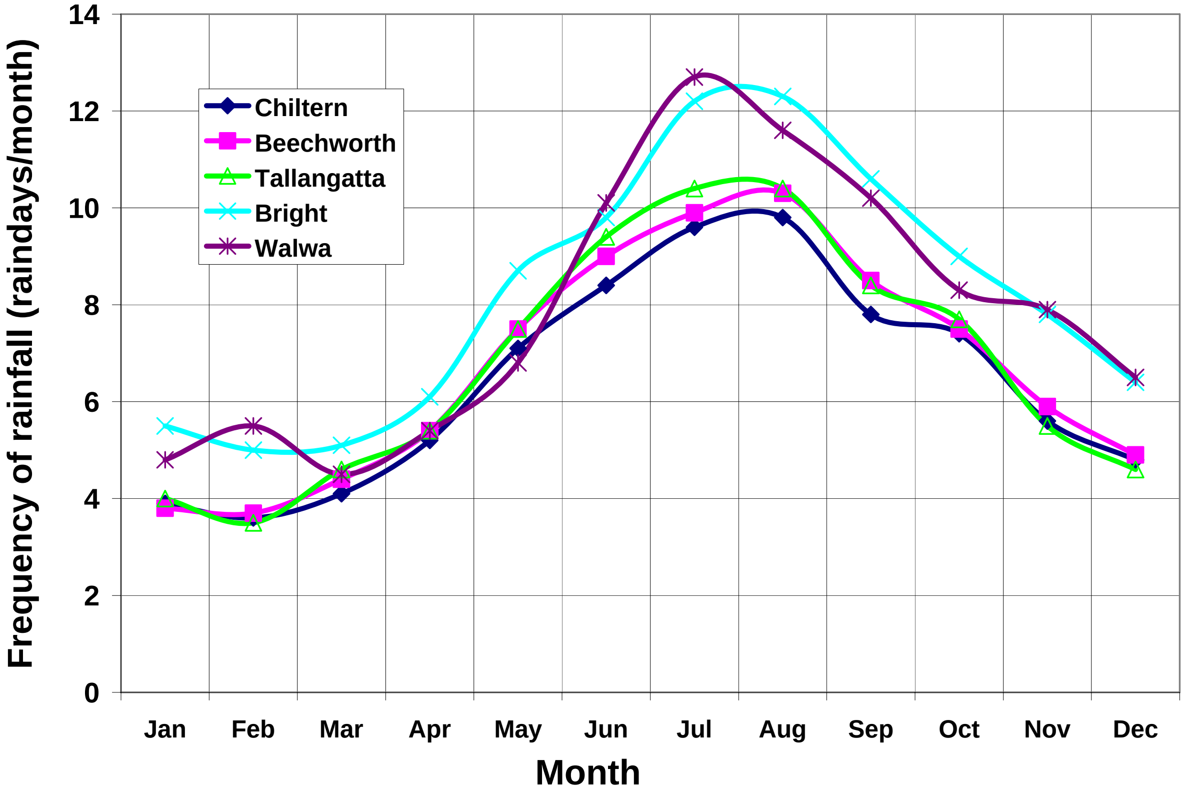

Figure 5.9: Seasonal variation in frequency of rainfall at selected locations

Figure 5.9 shows that the region is subject to higher frequencies of rainfall during the Winter seasons. Lower frequencies of rainfall are experienced during the Summer season. The difference in frequency of rainfall is more pronounced at the Walwa and Bright locations that are subject to higher rainfall.

Average annual maximum temperature

Daily maximum temperature is seen to influence water use behaviour, in particular outdoor water use, and is, therefore, an important indicator of the potential yields from rainwater tanks, stormwater harvesting and wastewater reuse. Average annual maximum temperatures at each of the zones used in this study are shown in Figure 5.10.

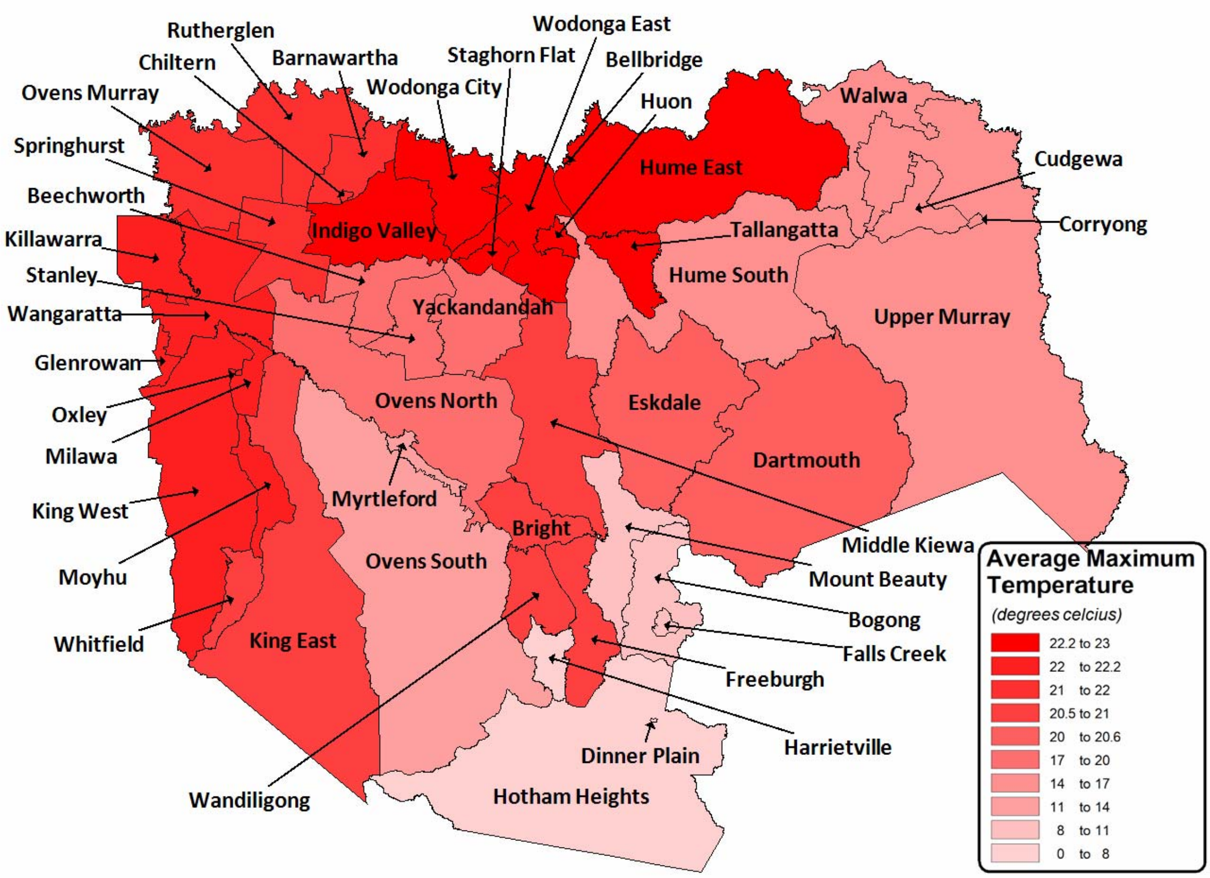

Figure 5.10: Spatial distribution of average annual maximum temperatures across North East Victoria

Figure 5.10 shows a wide variation in average annual maximum temperatures across the region with the highest annual average maximum temperature (22.2°C) occurring in the areas with lower elevations with the lowest annual average maximum temperature (7.9°C) occurring in the areas with higher elevations.

Mean monthly maximum temperature

The seasonal variation in average maximum temperatures at selected locations is presented in Figure 5.11.

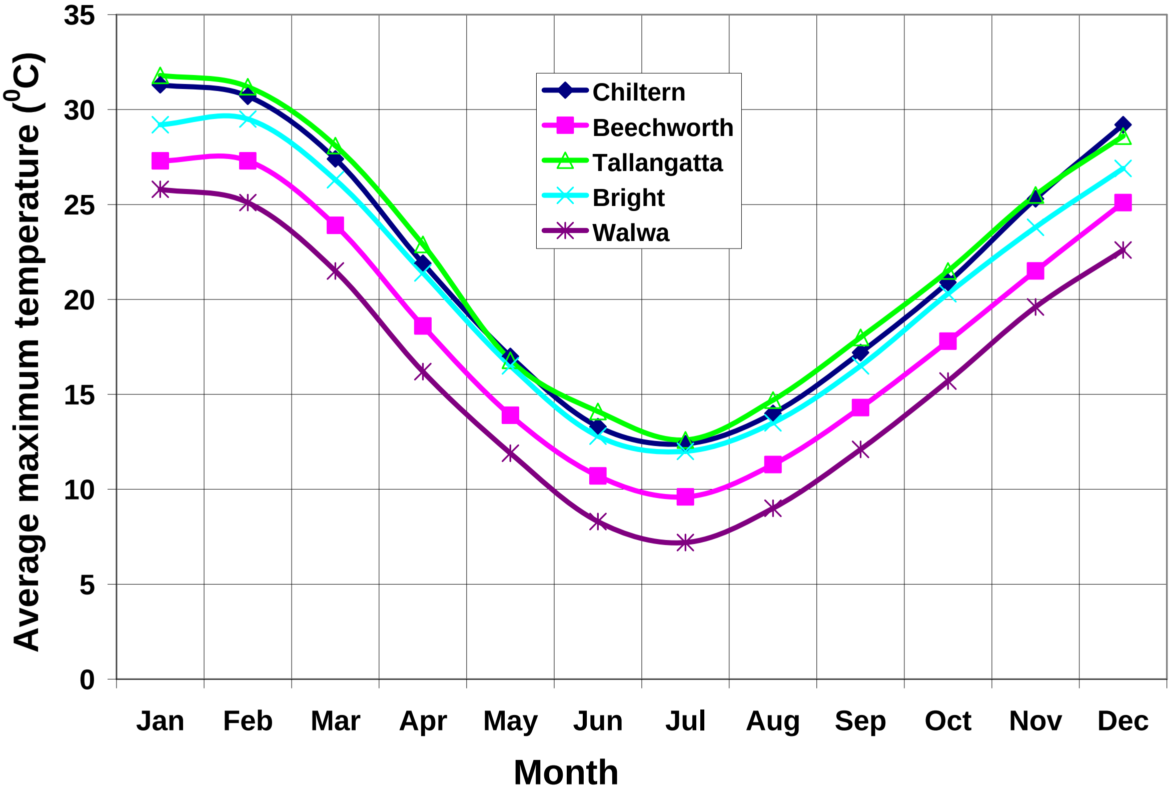

Figure 5.11: The seasonal distribution of average maximum temperatures at selected locations

Figure 5.11 shows that the seasonal distribution of temperature is similar for all locations with generally lower average temperatures in the Beechworth and Walwa zones. The distribution of average daily maximum temperatures displays greater spatial variation during the Summer season.

5.3 Demographics

A robust understanding of demographic behaviours is an important element of analysis of water resources strategies. We have utilised a range of accepted publications to derive a population profile for North East Victoria for the period 2010 to 2050. The profile is based on the number of dwellings present in each LGA over the given time period. Past demographic growth from 1996 to 2006 and current demographic growth for each LGA was derived using ABS 3218.2[8] series of publications.

The growth projections published by Department of Planning and Community Development (DPCD) in the Victoria in the Future 2011[9] report was utilised in this study. The spatial distribution of household income for the North East region is presented in Figure 5.12.

[8] Australian Bureau of Statistics, 3218.0 - Regional Population Growth, Australia, 2008-09, http://www.abs.gov.au/AUSSTATS
[9] Department of Planning and Community Development (2011). Victoria in the Future 2011.

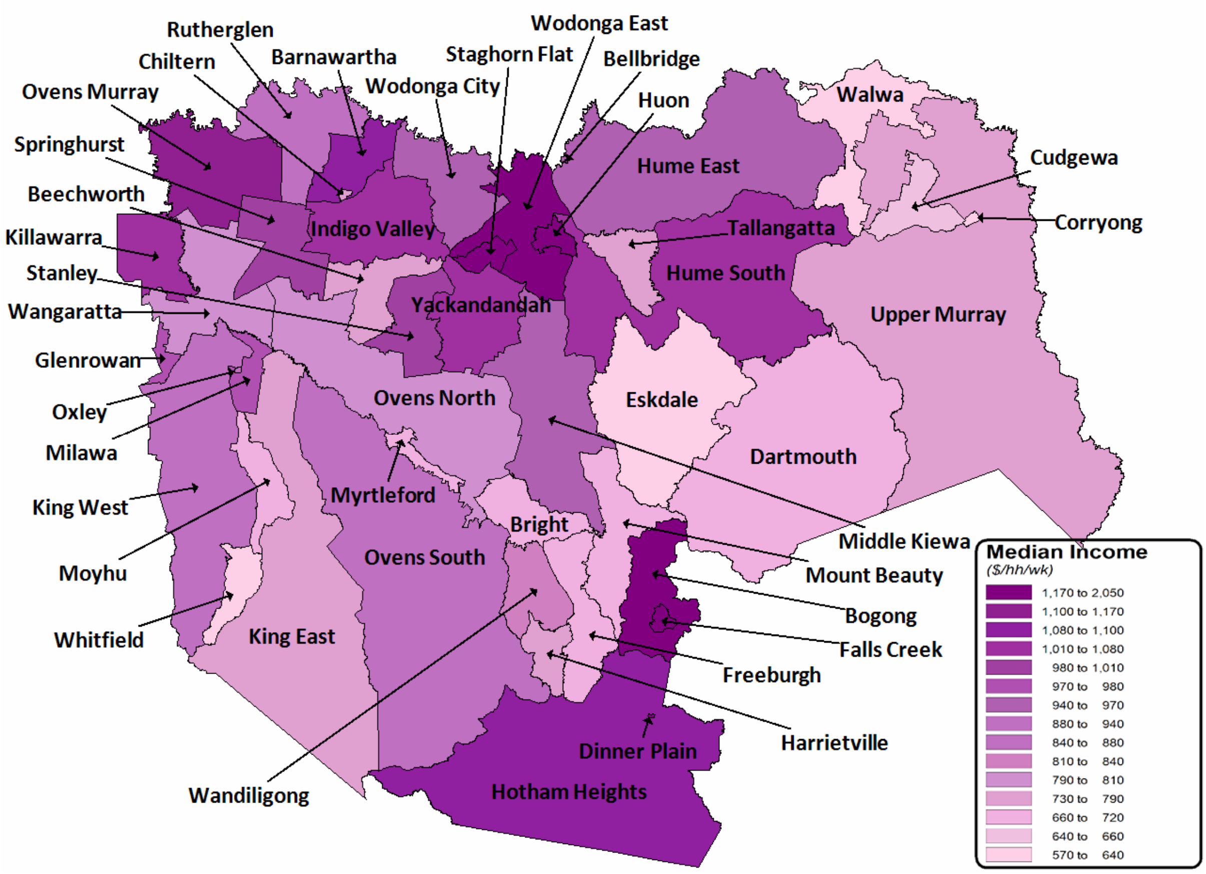

Figure 5.12: Spatial distributions of median household income across North East Victoria

Figure 5.12 shows that the region is subject to significant spatial variation in household income and that the areas with the lowest incomes (Eskdale, Whitfield, Corryong and Walwa) do not have traditional reticulated water or sewage services. The areas of North East Victoria with the highest household income include the established rural cities (Wodonga) and the high country resort areas (Falls Creek and Bogong).

The demographic information presented in this section was compiled to create the demographic growth profile used in the systems analysis of the North East region as shown in Table 5.9.

The renovation or redevelopment rate was derived from ABS 8731.0 series “Building Approvals”. The values of new dwellings and renovated (or redeveloped) dwellings reported in this document were used to derive the renovation rates for use in this study as a fixed proportion for each LGA of the overall total cost of a new dwelling.

It is important to note that the cost of a single average new dwelling has not been used for all of North East Victoria – the spatial costs of new dwellings that are vastly different in each zone were used in this study. The determination of the renovation or redevelopment rate for each zone is shown in Table 5.10.

Table 5.10 shows the renovation or redevelopment rate in each zone for renovations that incur expenses of greater than 10% of the value of an average dwelling and for renovations that are equal or greater than the cost of an average dwelling. The 10% renovation rate indicates the proportion of dwellings subject to partial renovation (such as a kitchen, a bathroom or a new extension) whereas the 100% renovation rate indicates the proportion of dwellings that are substantially redeveloped.

Table 5.9: Growth residential dwellings for each LGA in North East Victoria

Year	Population in each Local Government Area				
	Alpine	Indigo	Towong	Wangaratta	Wodonga
2010	12866	16111	6343	28938	36432
2011	12874	16144	6347	29002	36982
2016	13023	16635	6402	29585	39933
2021	13214	17187	6437	30295	43037
2026	13424	17738	6491	30987	45955
2031	13617	18210	6552	31556	48435
2036	13733	18565	6612	31950	50266
2041	13833	18870	6629	32260	51630
2046	13955	19199	6663	32628	52979
2051	14074	19528	6694	33012	54387

Table 5.10: Determination of the renovation rate at each LGA

SLA	Renovation rate (%) as a proportion of average dwelling value	
	100 % of Avg. value	10 % of Avg. value
Alpine (East)	0.52	5.25
Alpine (West)	0.24	2.41
Indigo (Part A)	0.54	5.41
Indigo (Part B)	0.23	2.34
Towong (Part A)	0.20	1.97
Towong (Part B)	0.14	1.38
Wangaratta (Central)	0.22	2.23
Wangaratta (North)	0.32	3.24
Wangaratta (South)	0.18	1.83
Wodonga	0.18	1.78

The values shown in Table 5.9 were used to define the development rate for each LGA throughout North East Victoria and the values in Table 5.10 were used to determine the rate of inclusion of alterative water management strategies.

5.4 Water demands

The performance of alternative water cycle management strategies is primarily dependent on the spatial distribution of water demands and climate process throughout a region. This section outlines the development of residential and non-residential water demands.

A summary of water demands within each town for the 2004-05 year is provided in Table 5.11 as sourced from the 2007 Water Supply Demand Strategy.[10] Note that these water demands from the period prior to significant regional water restrictions were used in this study to establish accurate baseline water demand behaviours for the region. These water demands are then modified in the systems analysis in response to adoption of water efficient appliances and behaviours, and by regional water restrictions.

Table 5.11: Distribution of water demands in towns with reticulated water supplies across North East Victoria

Town	Residential demand (kL/hh/yr)	Water demands (ML/yr)				
		Residential	Commerce	Industry	Other	Total
Barnawartha	356	77	8	0	13	97
Beechworth	313	386	182	1	153	700
Bellbridge	313	50	4	0	9	62
Bright	242	374	180	0	339	890
Chiltern	282	137	26	1	71	230
Corryong	309	196	92	11	73	370
Dartmouth	133	10	9	0	16	35
Eskdale	116	6	1	0	1	8
Glenrowan	287	37	21	0	26	84
Harrietville	218	36	25	0	9	71
Mount Beauty	213	242	85	0	133	460
Moyhu	327	30	8	0	8	46
Myrtleford	275	201	363	211	138	910
Oxley	360	41	1	0	19	61
Springhurst	268	20	3	0	8	31
Tallangatta	290	121	56	0	47	220
Wahgunyah	412	516	125	128	115	880
Walwa	294	14	11	0	10	34
Wangaratta	318	1118	2273	619	915	4900
Whitfield	255	11	7	0	18	37
Wodonga	308	3908	1358	784	1073	7100
Yackandandah	311	92	50	0	23	160

Table 5.11 also provides the average annual household water demands from each town. Note that the water demands for Eskdale were derived from the current draft Water Supply Demand Strategy for the region.[11]

[10] North East Water (2007). Water Supply Demand Strategy.
[11] North East Water (2011). 2010 Water Supply Demand Strategy.

Residential water demands

The use of average water demands and average household sizes to simulate the performance of alternative water management strategies produces considerable error.[12] Table 5.11 shows that the annual average household water demands are subject to considerable variation across the region with the highest demands experienced at Wahgunyah and the lowest demands observed at Eskdale. This variation is influenced by a range of factors including the distribution of dwelling types, household sizes, climate and income.

The performance of alternative water cycle management strategies or, indeed, any other water management strategy is primarily dependent on water use behaviour in each household and building. Water use behaviour is also influenced by household size and dwelling type. Information about average household water use for each month, distribution of household sizes and dwelling types were available for each State Suburb and Statistical Local Areas (SLA) from the Australian Bureau of Statistics.

Average water demands at any location are dependent on the distribution of household sizes (Figure 5.13) and dwelling types (Figure 5.14). As shown in Figure 5.13, for example, the distribution of household sizes is different for each type of dwelling and does not take the form of a normal distribution. Note that the distribution of household sizes is skewed toward smaller households for units and semi detached dwellings, and shows a more even distribution for detached housing.

As a consequence of the skewed distributions of household sizes and different types of dwellings, average water demands for an area cannot represent the water demands of an average household. Importantly, this type of average assumption cannot distinguish between the behaviour of different households and the performance of decentralised water management strategies in each of the households.

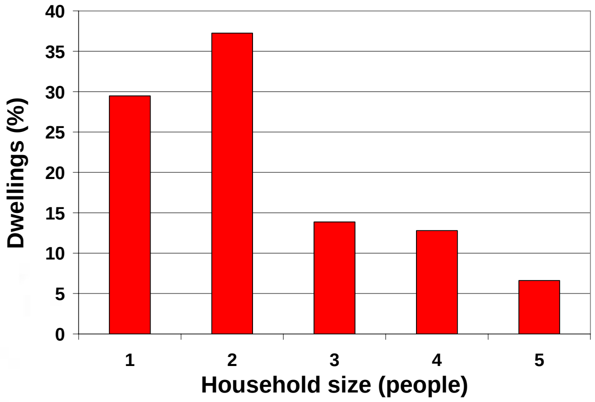

Figure 5.13: Distribution of household sizes at Beechworth

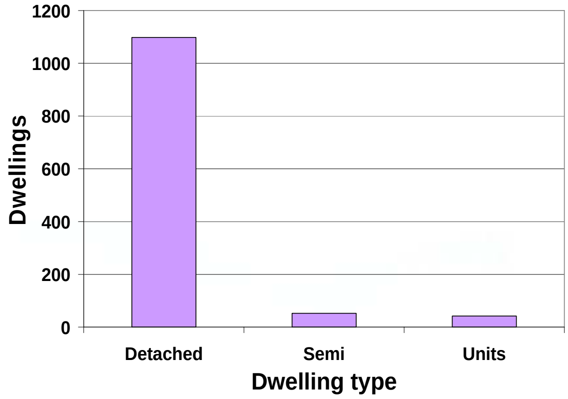

Figure 5.14: Distribution of housing types at Beechworth

As shown in Figure 5.14, for example, the dwelling stock in each area comprises a range of different dwelling types. Each dwelling type will also generate different behaviours that will influence the characteristics of household water use. For example, a detached house may allow the opportunity for significant outdoor water use whilst a unit dwelling is unlikely to provide opportunities for outdoor use.

[12] Coombes P.J. and M.E. Barry (2007). The effect of selection of time steps and average assumptions on the continuous simulation of rainwater harvesting strategies. Journal of Water Science and Technology. London.

The distributions of household sizes and dwelling types for an area provides an opportunity to disaggregate average water demand for an area into the likely water demands in each household. This task also requires an estimate of the proportion of water demand that is used outdoors.

Selection of the "base" water demand year

The availability of water use data that is disaggregated to the household scale is limited to recently available information. It is preferable that the base water demands used in analysis of water supply scenarios be derived for periods that were not subject to regional water restrictions. However, this was not possible for this study. During the 2004/05 period the region was subject to lower levels water restrictions.

In our calibration to the chosen period of "base water use" it was assumed that the lower levels of "water restrictions" were reasonable way to improve household scale water management and these changes in water using behaviours would be maintained in the future. Household water consumption for the period 2004/05 was selected in this study as the representing base water consumption for North East Victoria. Note that adoption of additional strategies including connection to wastewater reuse systems and other water efficiency programs were used to modify the base water demands in accordance with a range of time based growth in strategies. These impacts were included by simulation of a wide range of different water use strategies in different households and combining the different water use sequences for each zone.

The impacts of regional water restrictions were included in the simulations of water use for each zone after generation of the combined sequences of water use for each zone.

The PURRS (Probabilistic Urban Rainwater and wastewater Reuse Simulator) Model

A schematic of the basic processes in the PURRS (Probabilistic Urban Rainwater and wastewater Reuse Simulator) model is shown in Figure 5.15. The rainfall input to the model can be from pluviograph rainfall data, the DRIP (Disaggregated Rectangular Intensity Pulse) event rainfall model or a synthetic pluviograph rainfall generator[13]. The synthetic pluviograph rainfall generator can be used to create a rainfall pluviograph record from daily rainfall in locations where incomplete or no pluviograph data is available. A more complete description of the PURRS model is provided in the literature[14].

The PURRS model was utilised to generate lot and precinct scale responses including behaviour and climate driven water demands, adoption of water efficient appliances, sewage discharges and stormwater runoff that were spatially incorporated in the wider spatial systems framework. This analysis also includes a wide range of spatial processes including water efficient buildings, rainwater harvesting, local wastewater reuse and stormwater harvesting.

[14] Coombes P.J., 2006. Integrated Water Cycle Modeling Using PURRS (Probabilistic Urban Rainwater and wastewater Reuse Simulator). Urban Water Cycle Solutions.

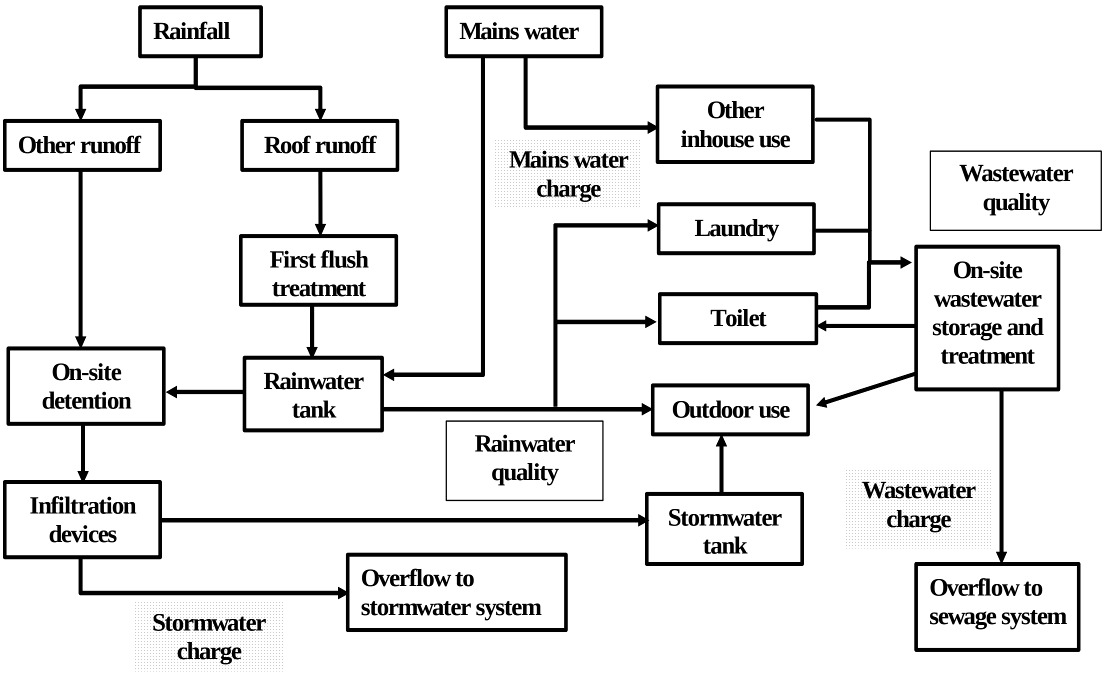

Figure 5.15: Example schematic of the basic processes in the PURRS water balance model

Figure 5.15 shows one of the many combinations of water cycle solutions that can be utilised within the PURRS simulation framework.

Considering outdoor water use

The variability of outdoor water use for various household types in different climate zones is not usually measured. In a rare study of household water use, Coombes[15] analysed indoor and outdoor water use in 192 houses across 5 climate zones and 12 years in the Hunter region of New South Wales and derived a relationship for estimating monthly average daily outdoor use:

$$OutdoorUse = 7.53M - 11.3AveR - 0.025Inc - 0.816Rdays + 24.44G + 19.08AveT - 251 \qquad (5.1)$$

where M is a seasonal index with values from 1 to 6 (January and December = 1; June and July = 6), Inc is the average income of people in the household, AveR is average monthly daily rainfall, G is annual population growth, Rdays is the number of rain days in each month and AveT is the average monthly daily maximum temperature.

This research provides some insight into the behavioural drivers of outdoor water demand. Outdoor water use was found to be independent of household size and garden area but was strongly correlated with climatic variables, measures of dryness, seasonal and socioeconomic variables. Importantly, the research revealed that the magnitude and sequence of outdoor water use is variable.

15 Donovan I. and P.J. Coombes, (1998; 1999 and 2001). WSUD discussion paper, Practice Notes and Water Smart Planning Provisions. The Hunter Regional Organisation of Councils. NSW. Australia.

Climate and demographic information from each zone was used in Equation 5.1 to provide an initial estimate of average daily outdoor water use. Importantly, Equation 5.1 also provides information about the likely temporal pattern of outdoor water use.

Outdoor water use is not a constant proportion of household water use throughout a year. As such the use of average proportions of outdoor water use in analysis of decentralised water management strategies will not provide a reliable understanding of the performance of measures at the household scale and, indeed, across the region. Equation 5.1 has been utilised to estimate the average proportions and the temporal patterns of outdoor water use for input to the water demand algorithms employed in the PURRS water balance model for this study.

It is should be noted that the water demand algorithms used in the PURRS model allow for climate generated daily and diurnal variation of water demands that use information from equation 5.1 as conditioning variables. The magnitude of the monthly outdoor water uses estimated using Equation 5.1 are then calibrated to measured local values provided by the North East Water to ensure that the annual average volumes of outdoor water uses are consistent with local behaviour. It is clear that there is limited knowledge of the magnitude and patterns of outdoor water demand. More comprehensive monitoring programmes are required to allow understanding of outdoor water use.

The Outdoor Water Use Model

Domestic outdoor water use such as garden watering, car washing and filling of swimming pools is seen to be a recreational pastime that is dependent on human behaviour. Outdoor water use behaviour is significantly modified by human reaction to daily temperature, days without rainfall and rainfall depth. The probability of outdoor water use is expected to increase as the length of a period without rainfall increases and the volume of water used is a function of temperature and normal water use patterns (the monthly average daily demand defined by Equation 5.1). People are more likely to use water outside of the house when it is hot and dry, and in accordance with habits.

During a day with rainfall there is a smaller probability of water use and the volume of water used is dependent on the rainfall depth. There is a chance of outdoor water use when people perceive rainfall depth to be insignificant and, conversely, when rainfall depth is perceived to be large there will be no outdoor water use. When that rainfall depth is sufficiently high, people may not use water outside of the house for a number of days. These behavioural considerations have been formalised into a probabilistic framework[16] that drives the daily simulation of outdoor water use. This climatic behavioural simulation approach is used in the PURRS model.

Considering indoor water use

Knowledge of the magnitudes of indoor water uses for a different household sizes across a variety of demographic and socioeconomic profiles is also limited. This investigation also utilised relationships from a

[16] Coombes P. J., G. Kuczera and J.D. Kalma, 2000. A behavioural model for prediction of exhouse water demand, 3rd International Hydrology and Water Resource Symposium, 793-798, Perth, Australia.

comprehensive long term study of household water uses[17] to estimate monthly daily average indoor water use inDem for a variety of household sizes in different regions:

$$inDem = 27.79 + 145.69P - 0.42M - 10.58AveR + 6.7Rdays - 0.16Inc - 12.28G + 0.49AveT \qquad (5.2)$$

where P is the number of occupants in a dwelling.

Indoor water use was found to be strongly dependent of household size and also demonstrated some correlation with climatic variables, measures of dryness, seasonal and socioeconomic variables. The research also revealed that the magnitude and sequence of indoor water use was also variable. Indoor water demand from different household sizes was estimated using Equation 5.2.

The estimated water demands using equation 5.2 reveal that the magnitude of indoor water demands is strongly dependent on household size and displays some seasonal variation. In addition, the relationship between household size and indoor water demands is not linear. These phenomena are consistent with the observations from recent research into household water use.[5,6,18,19.]

Equation 5.2 was used to estimate the magnitude of indoor water demands for different household sizes throughout North East Victoria for use in the PURRS water balance model. The indoor water demands estimated using Equation 5.2 were then calibrated using locally available measured water demands provided by SWC to ensure that simulations of indoor water demands are consistent with local behaviour.

The water use algorithms were then calibrated to observed water use in dwellings throughout the region. Note that the observations of residential water use were derived from rolling metering programs that do not directly measure sequences of water use.

It is important to highlight that there are limited measurements available to determine the magnitudes and patterns of indoor water uses in different sized households. Urban metering, monitoring and measurement practices need to be modified to improve understanding of household water use behaviours. Nevertheless, the likely water demands for each household in a given area can be approximated using the available observed data and some informed assumptions based on the equations presented in this report. Distributions of household size and dwelling types for each SLA were obtained from the ABS, and the average household water demands were provided by North East Water. This information can be used to disaggregate average water demands for an area into the likely water demands in each household.

The indoor water use values derived using Equation 5.2 for different household sizes and outdoor water use were combined with climate data in the water balance model PURRS. The performance of each different household was simulated. The simulated values for average annual indoor use for each household size are utilised to adjust the input values for indoor use so that the combined simulations equate to the previously calculated value for average indoor use. Similarly, the outdoor water use inputs to the model are adjusted to ensure that simulated long term average values for outdoor use equal the previously calculated values for average outdoor use.

It is important to note that the water demand algorithms in the PURRS model allow for climate generated daily and diurnal variation of water demands that use information from equations 5.1 and 5.2 as

[17] Coombes P.J., (2002). Rainwater tanks revisited – new opportunities of integrated water cycle management. PhD Thesis. The University of Newcastle. NSW. Australia.
[18] Cui L., M. Thyer., P.J. Coombes and G. Kuczera, 2007. A hidden state Markov model for identifying the long term dynamics of indoor household water uses. Rainwater and Urban Design 2007 Conference. Sydney Australia.
[19] Thyer M., M. Hardy., P.J. Coombes and C. Patterson, 2007. The impacts of end use dynamics on urban water system design criteria. Rainwater and Urban Design 2007 Conference. Sydney Australia.

conditioning variables. The PURRS demand algorithms allow for daily and diurnal variation of water use whilst maintaining the expected long term volumes of water use.

Indoor water end uses

Simulation of daily indoor uses in the PURRS model are based on the values estimated using Equation 5.2, diurnal patterns and a distribution of household indoor water uses into kitchen, laundry, toilet, bathroom and hot water uses. In this study the distribution of indoor water uses from the Yarra Valley Water area reported by Roberts[20] were modified for use in PURRS as shown in Figure 5.15.

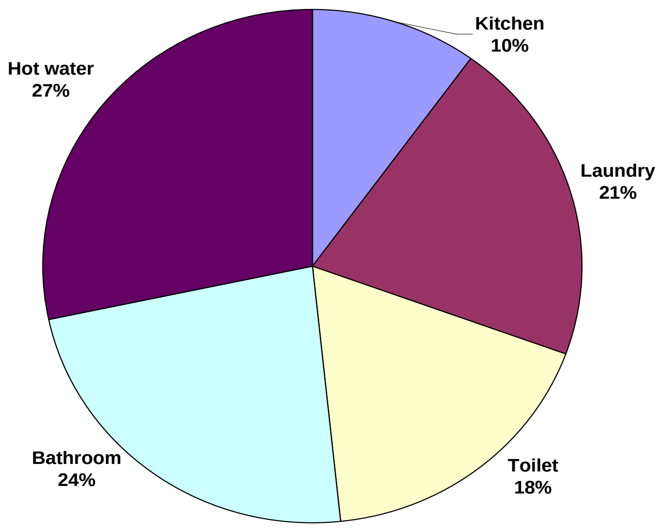

Figure 5.15: Distribution of household indoor water uses

The water use algorithms were also used to generate sewage discharges from each household and non-residential building throughout the region.

The proportion of indoor use via hot water services was determined to allow understanding of strategies that utilise the water quality improvement characteristics of domestic hot water services and to fully understand the potential to reduce the energy use for heating water by use of water efficient appliances. The water use algorithms were also used to generate sewage discharges from each household and non-residential building throughout North East Victoria.

The simulation of the performance of each dwelling cluster was assumed to include half of the road frontage to the allotment to account for stormwater runoff from the urban area. Dimensions of the dwelling clusters used in the simulations are presented in Table 5.12.

[20] Roberts P., 2006. End use research in Melbourne suburbs. Water. Australian Water Association. 51-55.

Table 5.14: dimensions of residential clusters used in the analysis

Dwelling type	Lot area (m^2)	Roof area (m^2)	Impervious area (%)	Outdoor use factor	Number of dwellings
Detached (BAU)	700	100	70	1.0	1
Semi detached (BAU)	500	100	70	0.1	1
Units (BAU)	2,000	600	90	0.05	10
Detached (small towns)	2,000	250	70	1.0	1
Semi detached (small towns)	1,000	120	70	0.1	1
Other (small towns)	2,000	600	90	0.05	10

Table 5.14 shows that individual detached and semi detached dwellings, and clusters of ten units were analysed. The roof areas of dwellings that were included in alternative water strategies within towns with reticulated water services were set at a maximum value to account for limitations on rainwater harvesting strategies. The stormwater harvesting strategies in the alternative strategies collects stormwater from all impervious surfaces. Note that the outdoor use factor accounts for the proportion of outdoor use at a detached dwelling that can be expected for other types of dwellings.

Non-residential water demands

This investigation has also included non-residential water demands from each of the zones. The proportions of water demands from residential, commercial, industrial and other sectors for North East is shown in Table 5.11.

Non-residential water demands are a significant proportion of the total urban water demand in the North East Victoria. The non-residential water demands from each zone that were included in this investigation are shown in Table 5.11 that shows that annual volumes of non-residential demands vary considerably across the region. In addition, urban water systems throughout the region are subject to relatively high losses.

Non-residential water demands were also simulated using the PURRS model that also accounted for alternative strategies for the non-residential sector. Water use information was collated with summaries of business categories (such as the Census of Land Use and Employment) and information about numbers of connections from SWC to estimate the land use and numbers of non-residential connections in each zone. Non-residential water demands were assumed to increase at the same rate as growth in total residential connection in each zone.

5.5 The transition framework

A transition framework was used to generate daily water cycle responses for each zone as shown in Figure 5.16. Sequences of daily water balance results from the PURRS model were compiled using seasonal information and historical climate data including daily rain depths, cumulative days without rainfall and average daily maximum ambient air temperature to create resource files of water demand, wastewater generation and stormwater runoff. The method of non-parametric aggregation[21] was utilised to generate daily water use, generation of wastewater and stormwater runoff for each dwelling type in each zone using the historical resource files and climate replicates generated for the simulation of the regional system.

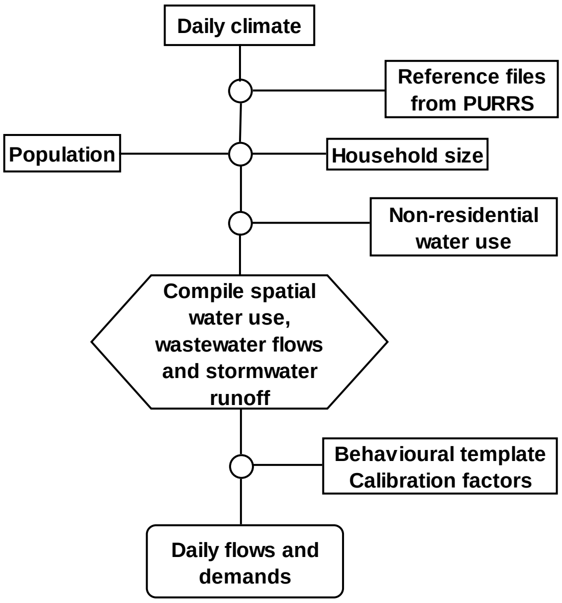

Figure 5.16: The transition framework

At each time step climate variables from the regional model are used to find matching climate variables and coincident daily water use, sewage generation and stormwater runoff results for each dwelling from the resource files. These results are combined with population, non-residential water use and demographic data at each time step to estimate total indoor and outdoor use, sewage flows and stormwater runoff for each zone.

The sequences of data from the PURRS simulations are combined in the transition framework using the framework presented in Figure 5.17. Daily sequences of water cycle information; such as water demands, wastewater discharges and stormwater runoff; are combined for different household sizes, different dwelling types and a combination of different water cycle management Options for each strategy in the Transition Model.

[21] Coombes P.J., G. Kuczera, J.D. Kalma and J.R. Argue. An evaluation of the benefits of source control measures at the regional scale. Urban Water. 4(4). London, UK. 2002.

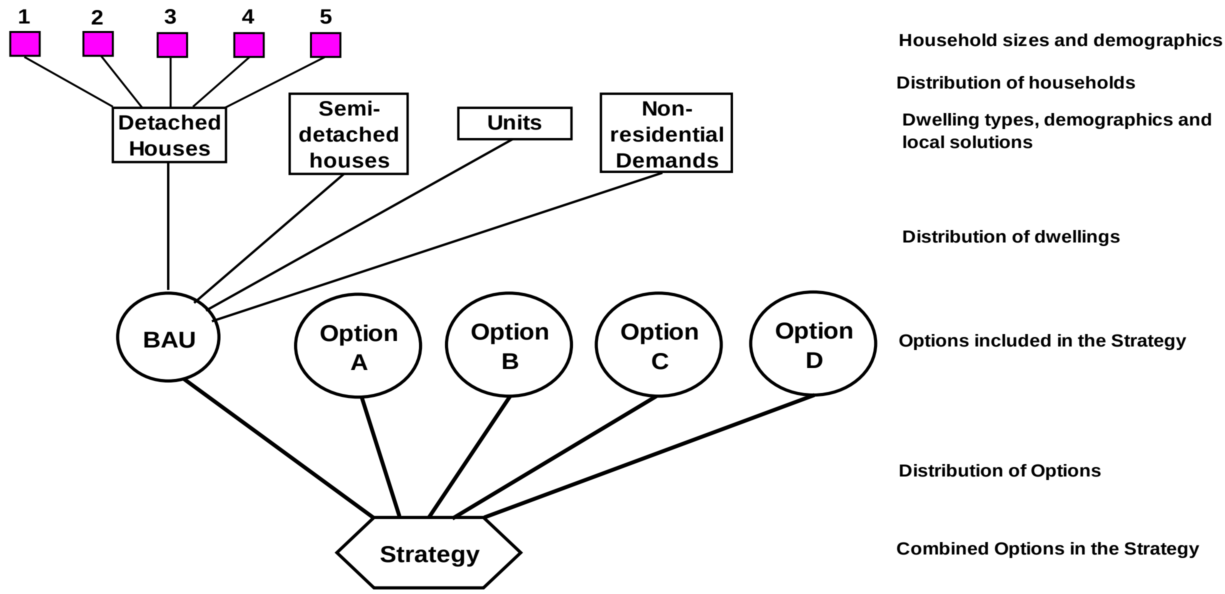

Figure 5.17: Structure for combining different household sizes, dwelling types and water cycle management Options in the Transition Model

The climate variables in the regional systems model were derived using the synthetic climate series generated using historical climate sequences. Importantly the climate replicates are temporally and spatially consistent with the rainfall and stream flows in the water supply catchments.

5.6 Regional systems

The WATHNET network linear program for water supply headworks simulation was utilised to analyse the combined water, sewage, wastewater reuse and waterway networks for each town, water district and river basin. A wide range of spatial information generated by the lot scale analysis was combined in the scale transition framework for use in the systems analysis.

The movement of water, sewerage, recycled water and stormwater throughout North East Victoria was simulated over a 40 year period using 100 replicates of climate sequences. This allowed analysis of peak flows in trunk infrastructure, assessment for regional sewerage discharges, stormwater runoff and water demands.

The schematics of the trunk water distribution, demand nodes and water supply headworks networks used in this study were provided by North East Water, the North East Catchment Management Authority and Goulburn Murray Water. This information was combined with the author's previous studies and data from the region to construct the major water flow paths employed in the systems analysis. In addition, extensive forensic examination of public documents was untaken to clarify a range of issues and confirm the efficacy of the information used in this analysis.

Details of the districts and towns with reticulated water services are provided in Table 5.15. Note that this investigation also includes towns that do not have reticulated water and sewage services.

Table 5.15: Water supply districts in the North East Region of Victoria

District	Towns	Water sources
Alpine	Bright and Wandiligong	Ovens River and Bakers Gully Creek
	Harrietville	Simmons Creek and Ovens River
	Mt Beauty, Tawonga and Tawonga South	West Kiewa River and Simmonds Creek
	Myrtleford	Buffalo Creek
	Porepunkah	Buckland River and Bright
Central	Barnawartha	Murray River (Wodonga Creek)
	Chiltern	Murray River (Wodonga Creek)
	Glenrowan	Ovens River (from Wangaratta)
	Springhurst	Murray River (Wodonga Creek)
King	Moyhu	King River
	Oxley	King River
	Whitfield	Musk Gully Creek (soon to be King River)*
Mitta Mitta	Eskdale	Mitta Mitta River
	Dartmouth	Mitta Mita River and Lake Tabor
	Tallangatta	Mitta Mitta River and Lake Hume
Murray	Bundalong	Murray River
	Rutherglen and Wahgunyah	Murray River
	Wodonga, Baranduda, Kiewa and Tangambalanga	Murray River (Wodonga Creek)
Ovens	Wangaratta	Ovens River and groundwater bores
Sub-Alpine	Beechworth	Nine Mile Creek, Frenchmans Creek and Lake Kerferd
	Yackandandah	Nine Mile Creek
Upper Murray	Bellbridge	Murray River and Lake Hume
	Corryong and Cudgewa	Nariel Creek
	Walwa	Murray River

*Construction of this project funded under the Small Towns Water Quality Fund is underway

Details of the districts and towns with reticulated wastewater services are provided in Table 5.16.

Table 5.16: North East Water wastewater systems

Wastewater System	Towns Serviced	Discharge Point
Baranduda	Baranduda, Kiewa, Tangambalanga, Killara, Bonegilla (Army barracks)	Wodonga wastewater system
Barnawartha	Barnawartha	On-site irrigation
Beechworth	Beechworth	Spring Creek and On-site irrigation
Bellbridge	Bellbridge	Agricultural irrigation
Bright - Porepunkah	Bright, Porepunkah	Ovens River and golf course irrigation
Chiltern	Chiltern	On-site irrigation
Corryong	Corryong	On-site irrigation
Dartmouth	Dartmouth	Mitta Mitta River
Mt. Beauty	Mt. Beauty, Tawonga South, Tawonga (Bogong Hotel area only)	Kiewa River
Myrtleford	Myrtleford	Ovens River
Rutherglen - Wahgunyah	Rutherglen, Wahgunyah	Agricultural and public open space irrigation
Tallangatta	Tallangatta	Agricultural irrigation
Wangaratta	Wangaratta	On-site, agricultural and public open space irrigation
Wangaratta (Trade Waste Plant)	Wangaratta (Bruck Textiles and Nuplex)	Fifteen Mile Creek
Wodonga	Wodonga	Murray River and industrial reuse and public open space irrigation
Yackandandah	Yackandandah	On-site irrigation

5.7 Economic considerations

When considering the economics of the system it is important to account for the economic transfers within the system. Broadly, they can be described as economic costs and benefits. There are a number of levels of expenses and revenues, or benefits within a system.

From an economic perspective, there are costs involved in the regional and retail provision of water and wastewater services. There are also associated costs with the impact on the environment of activities such as disposal of wastewater in waterways and oceans, or the impact of constructing a new dam or desalination plant. On the other side of the ledger are a series of economic benefits from the provision of water services. These include the provision of utility and amenity to individuals and society though the provision of water and wastewater services. Benefits are also derived by returning water to certain environments and ecosystems. It is important to holistically consider all of these economic costs and benefits.

Our economic analysis evaluated the detailed transactions involved in the transfer of services from the bulk water supplier to water retailer and North East Victoria with consequent charges (revenue earned) for these services. In addition, the economic analysis considers the impacts of stormwater runoff and sewage discharges to water quality in waterways, and on urban flooding.

It is important to consider both the economic and financial aspects of the provision of services when undertaking a systems analysis of the provision of water services. The economic analysis includes the revenue earned by North East Water from developer, fixed and variable charges to connected properties in each zone for water and wastewater services.

Delivery of these services has been defined as extension, renewal, transfer and treatment costs of operating the water and wastewater systems. The foundation elements of these expenses and revenues are imbedded in the dynamic analysis of the spatial economics for water and wastewater services as shown in Figures 5.18 and 5.19 respectively.

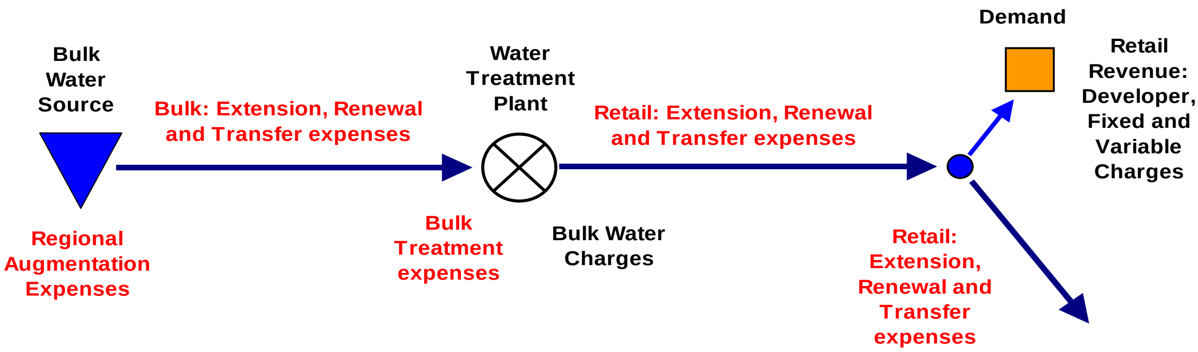

Figure 5.18: Foundation elements for water systems in the dynamic economic analysis

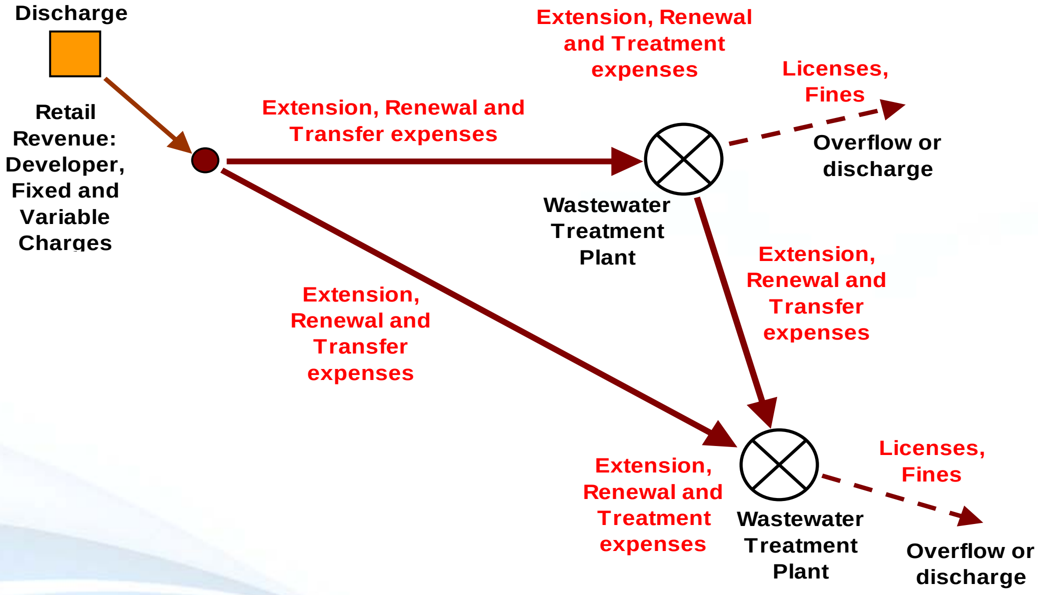

Figure 5.19: Foundation elements for wastewater systems in the dynamic economic analysis

Figures 5.18 and 5.19 demonstrate that extension, renewal and transfer costs are included in the spatial systems analysis for each of the basic transfer elements in the network. Transfer of water from one location to another requires the use of infrastructure and a range of associated resources that are included using this methodology.

Note that the costs associated with transfer of additional flows in the sewage networks generated by infiltration of stormwater are also included in this method. Moreover, the financial impacts of alternative water strategies that may have some reliance on the existing centralized network are also counted in this method – failure to supply sufficient water from (say) a stormwater harvesting system at a given spatial location will require additional water supply from the centralized system which may generate a requirement to augment the central systems and incur extension costs.

Extensions, renewals, transfer and treatment costs have been derived for each area from local information wherever possible as follows:

- **Extensions** – The cost to augment infrastructure to meet each additional unit of demand
- **Renewal** – The annual cost of renewing (or replacing) existing infrastructure for each unit of demand
- **Transfer** – The local costs to transfer water and sewage throughout the system
- **Treatment** – The local costs to treat water and sewage throughout the system

The economic analysis also includes bulk water charges levied by the Goulburn Murray Water, dividends paid to the Victoria Government (determined to be 13% of gross revenue), Company taxation (defined as 30% of profit), augmentation of wastewater treatment capacity and management of biosolids.

In addition, provision of these services includes the costs of augmentation of local and regional water supplies. Throughout the analysis financial values are their real value. Long time sequences of financial transactions presented in the Methods section for illustrative purposes are the nominal value.

Key data sources and assumptions underpinning the economic analysis

A number of data sources have been used in the development of this economic analysis as follows:

- “water price review 2009-10 to 2012-13” and supporting documentation published by the Victorian Essential Services Commission (ESC)
- “2009-10 National Performance Report - Urban water utilities” published by the Water Services Association of Australia
- “North East Water Annual Report 2010-11” published by North East Water
- Confidential data provided by North East Water

Information from the 2010-11 financial year has been used wherever possible in the development of the economic analysis. Alternatively, information from the 2009-10 year has been used and calibrated to enable comparative analysis. Key assumptions are listed below in Table 5.17.

Table 5.17: Assumptions underpinning economic analysis

Category	Criteria
CPI	2.5%
Base year	2010
Discount rate	9%

5.8 Constituents in wastewater

A range of wastewater quality indicators were also used to analyse the performance of the Options including Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and Total Nitrogen (TN). The median concentrations of each indicator were derived using sampling results from 20 wastewater treatment plants as shown in Table 5.18.

Table 5.18: Base concentrations of key indicators

Indicator	Concentration (t/GL)
BOD	247
TSS	294
TDS	429
TN	44

The values for the key indicators shown in Table 5.18 were used to analyse the changes in constituent loads discharging to existing wastewater plants and waterways.

5.9 Greenhouse gas emissions

The potential for climate change will have significant impacts on human and natural systems. There is a need to adapt our cities to be resilient in response to climate change and to reduce emissions of greenhouse gasses to mitigate further changes in climate regimes. This study has evaluated energy uses of key water cycle infrastructure to assess the impacts of each Option on greenhouse gas emissions. The translation factor of 1.26 kg CO_2 for each kWh of energy use for Victoria published by the Department of Climate Change was utilised in this analysis.[22]

Our analysis includes the spatial energy characteristics of sourcing, transporting and disposing of water and sewage throughout North East Victoria. Information about the energy use of various elements of the Options were utilised from a wide range of sources for use in this investigation including: Benchmarking report published by the National Water Commission, data provided North East Water, research publications and the annual reports.

The energy balance for the region was combined with a range of published results for different elements of the water cycle to generate energy use for the range of elements evaluated in this study as presented in Table 5.19.

[22] Department of Climate Change (2009). National Greenhouse Account Factors

Table 5.19: Energy use of various elements of the water cycle options

Item	Energy use (kwH/ML)
Water treatment (average)	259
Water distribution (average)	257
Wastewater treatment (average)	432
Wastewater distribution (average)	65
Membrane Bioreactors	750
Rainwater and stormwater harvesting distribution	900
Treatment of rainwater and stormwater	500
Distribution of treated wastewater	250
Water efficient appliances	-9.9

The values for energy use from Table 5.19 were used in the systems analysis to provide understanding of the greenhouse gas emissions associated with the different Options for water cycle management in North East Victoria. The energy use of the precinct scale MBR plants was estimated to be 750 kWh/ML and the energy required to distribute the treated wastewater was 250 kWh/ML.[23,24] Note that the energy use of MBR plants in Europe and Singapore range from 550 kWh/ML to 900 kWh/ML.

Importantly, the economic and energy efficiency of MBR systems are subject to ongoing improvements.[25] It is often claimed that MBR systems use more energy due to a requirement for air scouring of membranes. However, the energy efficiency of MBR plants is actually a function of overall plant design, operation and downtime.[26] The common practice of designing and establishing MBR plants in the same schematic as traditional wastewater treatment plants (such as IDAL) is a key driver for inefficiencies – MBR plants must be designed, established and optimised as MBR plants to achieve high levels of economic and energy efficiency.

Installation of water efficient clothes washers is expected to reduce energy use by 3.5 kWh/ML of water saved.[27] Energy savings from water efficient showers and dishwashers was estimated to be 6.4 kWh/ML.

[23] Coombes P.J., A. Cullen and K. Bethke (2011). Toward sustainable cities – Integrated water cycle management (IWCM) at an existing principal activity centre at Doncaster Hill. 33rd Hydrology and Water Resources Symposium. Engineers Australia.
[24] Wallis-Lage C.L., and S.D. Levesque (2009). Cost Effective and Energy Effiecent MBR systems. SIS09.
[25] General Electric (2011). GE's next generation MBR wastewater treatment system slashes energy use, boosts productivity.
[26] Livingston D., and K. Zhang (2011). Energy efficiency of MBR. Water and Wastes Digest.
[27] PMSIEC (2007). Water for Our Cities: building resilience in a climate of uncertainty. Section by Coombes on household energy use. Report by the Prime Minister's Science, Innovation and Engineering Council working group. The Australian Government. Canberra.

6 Results and Discussion

The results of the systems analysis of climate, demographic and water cycles throughout North East Victoria are presented in this Section. An explanation of climate processes and the potential of water cycle management Options at spatial and regional scales are provided. This unique systems analysis has provided a wealth of information about the behaviour of the North East region that will continue to inform discussion for some time. An overview of the key insights and discussions generated by the analysis are provided in this Section.

6.1 Climate

This study utilised the longest available daily rainfall records that include the recent drought for each zone within the region. Considerable spatial variation of average annual rainfall depths ranging from 582 mm to 1,818 mm were observed for North East Victoria. This is a significant result that highlights that rainfall regimes cannot be described by average or generalisations.

Analysis of the rainfall sequences at each location revealed a high variability of annual rainfall across the region and the relative reliability of rainfall – annual rainfall depths range from 263 mm to over 3,321 mm and annual rainfall depths of less than 300 mm are rare. Importantly, these areas have not experienced a year without rainfall and the rainfall sequences display cycles of higher and lower rainfall as demonstrated in Figure 6.1.

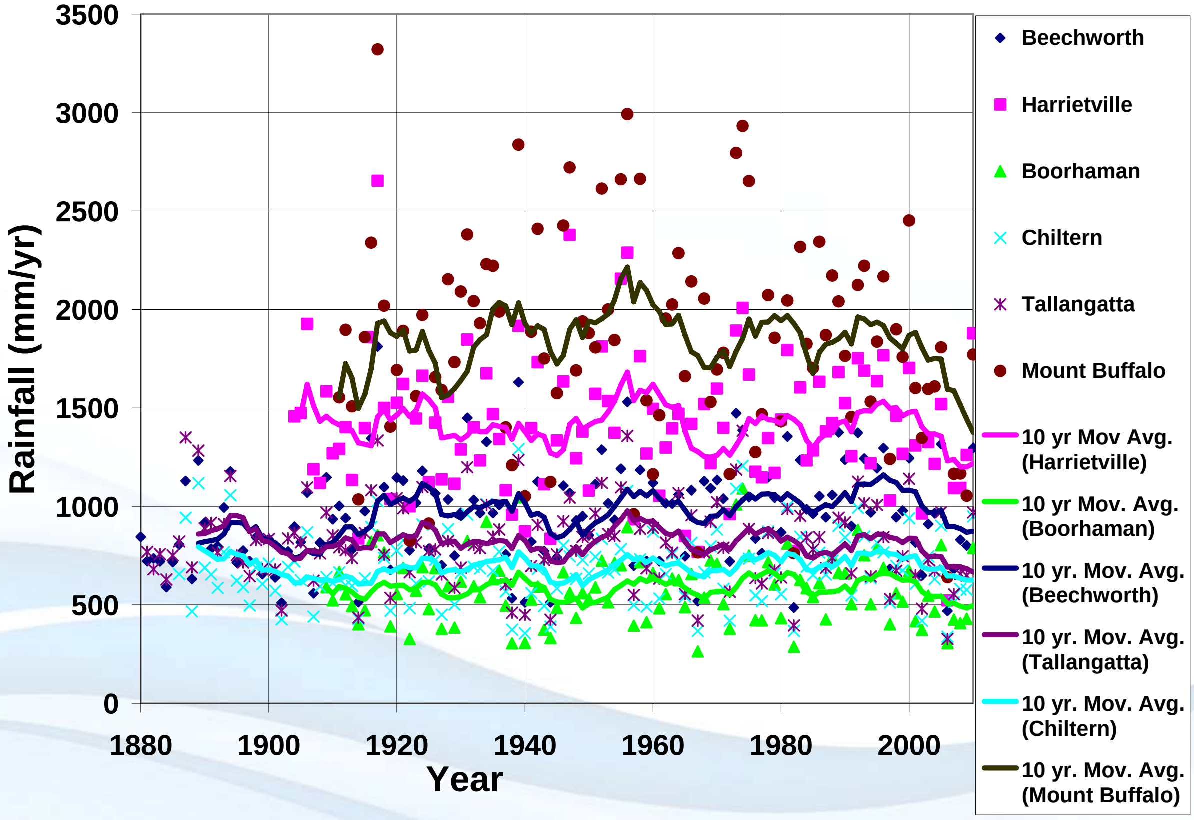

Figure 6.1: Selected rainfall sequences within the North East region

Figure 6.1 reveals that annual rainfall is highly variable over time and throughout North East Victoria. It is also clear that the region has not been subject to a “step change” in rainfall regimes. The rainfall regime for the region can best be described as cyclic patterns of wet and dry periods throughout recorded history. The rainfall records within the region display a range of behaviours including long term trends of decline (Mount Buffalo and Harrietville), increases in annual rainfall depths (Tallangatta) and some locations are not subject to changes in annual rainfall depths (Chiltern, Boorhaman and Beechworth).

The areas with high annual rainfall depths are subject to long term decline in rainfall and areas with relatively lower annual rainfall do not show any significant change in annual rainfall. It is noteworthy that Tallangatta is subject to a long term trend of increased rainfall. Clearly the behaviour of rainfall throughout North East Victoria cannot be described in general terms and rainfall throughout the region cannot be represented by a single rain gauge (such as Hume Reservoir).

The patterns of rainfall within entire rainfall records were examined to understand the impact on annual rainfall depths created by the recent drought by comparing the average rainfall from entire records to rainfall during the recent drought (the period from 2000 to 2010). In addition, evidence of a step change in annual rainfall depths was sought by comparing the average annual rain depth of the entire records to the average annual rain depths in the period after 1950 (the period 1950 to 2010). In addition the average rainfall depths from the period prior to 1950 were compared to the average rainfall depths of the period after 1950. The results of this investigation are provided in Table 6.1 for rainfall records within the North East region.

Table 6.1: Change in annual rainfall throughout North East Victoria

Criteria	Max (%)	Min (%)	Avg (%)
Recent drought (2000 to 2010)	-19.5	-4.8	-10.3
Change (post 1950 versus entire record)	+6	-1.8	+1.7
Change (post 1950 versus prior 1950)	+11.9	-1.8	+3.9

Table 6.1 reveals that rainfall within North East Victoria displayed a highly variable response to the recent drought ranging from a small decrease in annual rainfall to a significant decrease. Nevertheless, the average response to the recent drought was a 10.3% decrease in rainfall. However, there was no evidence that rainfall would cease at any location throughout North East Victoria.

It is noteworthy that daily maximum temperatures observed at the Rutherglen Research gauge increased by 4% (0.9°C) during the recent drought.

It is also revealed in Table 6.1 that there was no evidence of a step change to reduced rainfall throughout the region. However, there was a clear trend to increased rainfall throughout the region in comparison to pre 1950 rainfall and entire rainfall records. In addition, daily maximum temperatures in the period after 1950 were observed to decrease by 1% in comparison to pre 1950 temperatures.

The lengths of rainfall records used in this study were sufficient to capture the natural variation and extremes in rainfall at each location. Use of this data allows robust understanding of the performance of existing systems and alternative strategies. There is sufficient depth of annual rainfall, even during low rainfall years, for significant rainwater and stormwater yields at all locations throughout North East Victoria.

The region is subject to a wide variation of the frequency of rainfall in a year as defined by the number of days with rainfall greater than 1 mm and a relatively even distribution of rainfall across seasons. The region experiences an average of 87 rain days in any year. The frequency of rain days across North East Victoria ranges from rainfall occurring every 3 to 6 days. The rainfall regimes are eminently suitable for highly efficient rainwater and stormwater harvesting strategies.

6.2 Streamflow

Streamflows in the river catchments is presented in Figure 6.2 and is mostly characterised by significantly higher streamflow during the period 1950 to 1970 and cyclic patterns of lower and higher streamflow throughout the records.

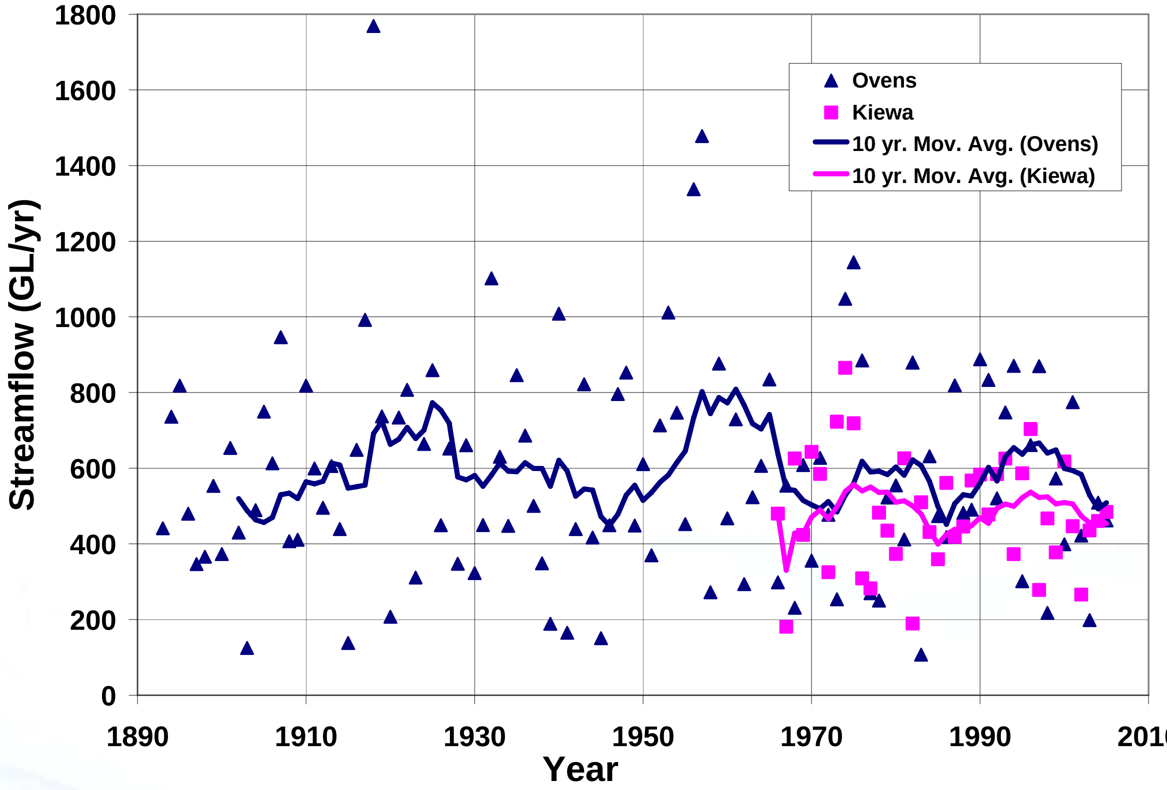

Figure 6.2: Sequences of streamflow from river basins in the North East Victoria

Figure 6.2 reveals that the water supply catchments are subject to highly variable annual streamflows that includes cyclic patterns of wet and dry periods.

The streamflow records do display considerable variation in annual flows but do not reveal evidence of a step change in the regime of streamflows. These streamflow records were used to assist with determination of the hydrology of the water supply catchments.

The streamflow within entire records were examined to understand the impacts created by the recent drought by comparing the average streamflow from entire records to streamflow during the recent drought (the period from 2000 to 2008). In addition, evidence of a step change in annual streamflow was sought by comparing the average annual streamflows of the entire records to the average annual streamflows in the period after 1950 (the period from 1950 to 2008). Average streamflow from the period prior to 1950 were compared to the average streamflow of the period after 1950. The results of this investigation are provided in Table 6.2 for streamflows within the water supply catchments.

Table 6.2: Change in annual streamflow in the water supply catchments

Criteria	Max (%)	Min (%)	Avg (%)
Recent drought (2000 to 2008)	-37.9	-16.5	-25.6
Change (post 1950 versus entire record)	+2.6	-1.2	+0.8
Change (post 1950 versus prior 1950)	+5.3	-2.3	+1.7

Table 6.2 reveals that significant decreases in streamflow were experienced within the water supply catchments during the recent drought. The average response to the recent drought was a 25.6% decrease in annual streamflow.

It is also revealed in Table 6.2 that there was no evidence of a significant step change to reduced streamflow throughout the water supply catchments. Indeed, there was a trend to increased streamflow throughout the water supply catchments in comparison to pre 1950 regimes.

Clearly the streamflow regimes have returned to "normal" or pre 1950 patterns throughout the water supply catchments supplying North East Victoria. Importantly, during periods of droughts small reductions in rainfall generate large reductions in runoff into rivers because increasing temperature regimes produce large losses in water supply catchments due to evapotranspiration.

6.3 Residential water demand

Metered quarterly water use from households, distribution of household sizes and dwelling types, average weekly income, average age and a range of climate parameters from each location were utilised to derive the lot scale water demands employed in this study.

Importantly, household water use was found to be dependent on climate and demographic parameters that vary widely across the region. The spatial variation of household water use across North East Victoria is influenced by income, minimum and maximum temperatures, rainfall depths and frequency of rainfall.

The range of spatial variation of parameters influencing water use indicates that the use of global averages to represent water demands for the North East region will produce misleading understanding of water planning, analysis of alternative water sources and water conservation strategies. Importantly, household sizes and dwelling types are not normally distributed or spatially consistent throughout the region which renders the use of averages unreliable. The pattern of these distributions is also highly variable across North East Victoria.

This study has revealed a paucity of knowledge about household water use behaviour throughout North East Victoria. Current and historical metering programs do not provide sufficient information to allow a robust understanding of the highly variable water use behaviour throughout the region. There is only limited information available to understand the drivers for indoor and outdoor water use. The ongoing focus on averaging or generalising water use generates a limited understanding.

6.4 Climate Change

The impact of the climate change scenarios on the North East in 2050 is presented in Table 6.3.

Table 6.3: Impact of the climate change scenarios for North East Victoria by 2050

Change in criteria	LE	HE
Average maximum temperature (°C)	+0.85	+2.05
Potential evaporation (%)	+4	+9
Annual average rainfall (%)	-9	-18
Streamflow (%)	-25	-45

Table 6.3 shows that the climate change scenarios generate moderate reductions in average annual rainfall and large reductions in streamflow in rivers by 2050. This result indicates that the availability of regional water resources will be dramatically diminished by 2050.

6.5 Lot scale results

The performance of each Option is presented in this Section for selected zones to demonstrate the potential of each strategy. This potential of the WEA Option is presented in Table 6.4.

Table 6.4 demonstrates that the water efficient appliances and gardens (WEA) will produce consistent reductions in demand for reticulated water supply of 23% to 43% in dwellings throughout North East Victoria. Importantly this Option also reduces wastewater discharges from dwellings by 16% to 39%.

The variation in the reductions in water demands and sewage discharges throughout the region are created by the different magnitudes of indoor and outdoor water demands.

Table 6.4: Impacts of the WEA Option in each zone

LGA	Reduction (%)		
	Water	Wastewater	Stormwater
Barnawartha	34	25	0
Beechworth	43	31	0
Bellbridge	34	25	0
Bogong	23	22	0
Bright	32	25	0
Chiltern	33	25	0
Corryong	27	25	0
Cudgewa	30	25	0
Dartmouth	32	25	0
Dinner Plain	25	25	0
Eskdale	32	25	0
Falls Creek	25	25	0
Freeburgh	33	25	0
Glenrowan	43	25	0
Harrietville	24	24	0
Hotham Heights	25	25	0
Hume East	34	25	0
Hume South	30	25	0
Huon	34	24	0
Indigo Valley	34	25	0
Killawarra	34	25	0
King East	33	25	0
King West	34	25	0
Middle Kiewa	33	25	0
Milawa	35	25	0
Mount Beauty	25	24	0
Moyhu	34	25	0
Myrtleford	25	23	0
Ovens Murray	36	25	0
Ovens North	30	24	0
Ovens South	27	25	0
Oxley	34	25	0
Rutherglen	32	22	0
Springhurst	34	25	0
Staghorn Flat	35	25	0
Stanley	31	25	0
Tallangatta	33	24	0
Upper Murray	31	26	0
Walwa	42	39	0
Wandiligong	28	23	0
Wangaratta	26	25	0
Whitfield	25	16	0
Wodonga City	27	26	0
Wodonga East	32	27	0
Yackandandah	37	28	0

The performance of the RWH Option is presented in Table 6.5.

Table 6.5: Impacts of the RWH Option in each zone

LGA	Reduction (%)		
	Water	Wastewater	Stormwater
Barnawartha	64	25	33
Beechworth	68	41	26
Bellbridge	61	25	38
Bogong	54	22	11
Bright	66	25	13
Chiltern	65	25	30
Corryong	56	25	25
Cudgewa	59	25	27
Dartmouth	69	25	12
Dinner Plain	57	25	4
Eskdale	69	25	12
Falls Creek	57	25	9
Freeburgh	68	25	13
Glenrowan	43	25	13
Harrietville	56	24	11
Hotham Heights	57	25	12
Hume East	63	25	28
Hume South	59	25	26
Huon	63	24	28
Indigo Valley	66	25	26
Killawarra	58	25	39
King East	61	25	27
King West	61	25	36
Middle Kiewa	65	25	19
Milawa	61	25	34
Mount Beauty	56	24	16
Moyhu	61	25	41
Myrtleford	54	23	26
Ovens Murray	63	25	34
Ovens North	60	24	26
Ovens South	58	25	10
Oxley	59	25	44
Rutherglen	55	22	46
Springhurst	62	25	38
Staghorn Flat	65	25	26
Stanley	60	25	24
Tallangatta	63	24	33
Upper Murray	44	26	14
Walwa	39	39	34
Wandiligong	51	23	16
Wangaratta	39	25	40
Whitfield	46	16	51
Wodonga City	40	26	39
Wodonga East	41	27	38
Yackandandah	42	38	27

Table 6.5 demonstrates that the RWH Option generates reductions in water demand of 43% to 69% in dwellings throughout North East Victoria. This Option also reduces wastewater discharges from dwellings by 16% to 39% and stormwater runoff from allotments by 9% to 51%.

The performance of the WWR Option is presented in Table 6.6.

Table 6.6: Impacts of the WWR Option in each zone

LGA	Reduction (%)		
	Water	Wastewater	Stormwater
Barnawartha	64	61	0
Beechworth	68	75	0
Bellbridge	63	59	0
Bogong	49	74	0
Bright	63	70	0
Chiltern	64	67	0
Corryong	53	74	0
Cudgewa	58	74	0
Dartmouth	64	71	0
Dinner Plain	50	74	0
Eskdale	64	72	0
Falls Creek	50	74	0
Freeburgh	64	69	0
Glenrowan	43	48	0
Harrietville	49	74	0
Hotham Heights	50	74	0
Hume East	64	63	0
Hume South	60	72	0
Huon	64	56	0
Indigo Valley	64	62	0
Killawarra	64	60	0
King East	63	67	0
King West	64	60	0
Middle Kiewa	63	68	0
Milawa	64	59	0
Mount Beauty	51	74	0
Moyhu	64	63	0
Myrtleford	52	74	0
Ovens Murray	65	47	0
Ovens North	60	73	0
Ovens South	53	74	0
Oxley	64	61	0
Rutherglen	63	60	0
Springhurst	64	62	0
Staghorn Flat	64	57	0
Stanley	61	70	0
Tallangatta	63	65	0
Upper Murray	42	65	0
Walwa	41	66	0
Wandiligong	45	56	0
Wangaratta	45	45	0
Whitfield	46	57	0
Wodonga City	45	47	0
Wodonga East	44	45	0
Yackandandah	43	60	0

Table 6.6 shows that the WWR Option generates reductions in water demand of 43% to 69% and reduces wastewater discharges by 45% to 75%.

The performance of the IWCM Option is presented in Table 6.7.

Table 6.7: Impacts of the IWCM Option in each zone

LGA	Reduction (%)		
	Water	Wastewater	Stormwater
Barnawartha	72	61	24
Beechworth	74	75	19
Bellbridge	72	59	28
Bogong	56	74	8
Bright	69	70	10
Chiltern	71	66	22
Corryong	60	74	18
Cudgewa	64	74	20
Dartmouth	70	71	9
Dinner Plain	57	74	3
Eskdale	69	72	9
Falls Creek	58	74	7
Freeburgh	71	69	10
Glenrowan	43	47	10
Harrietville	57	74	8
Hotham Heights	57	74	9
Hume East	71	63	21
Hume South	66	72	19
Huon	73	56	21
Indigo Valley	72	62	19
Killawarra	72	60	29
King East	70	67	20
King West	72	60	26
Middle Kiewa	70	68	14
Milawa	72	59	25
Mount Beauty	57	74	12
Moyhu	72	63	30
Myrtleford	58	74	19
Ovens Murray	74	47	25
Ovens North	67	72	19
Ovens South	60	74	7
Oxley	72	61	32
Rutherglen	70	60	34
Springhurst	72	63	28
Staghorn Flat	73	57	19
Stanley	68	70	18
Tallangatta	71	65	24
Upper Murray	50	65	10
Walwa	49	66	25
Wandiligong	55	56	12
Wangaratta	57	45	29
Whitfield	55	57	38
Wodonga City	57	47	29
Wodonga East	58	45	28
Yackandandah	54	60	20

Table 6.7 demonstrates that the IWCM Option generates reductions in water demand of 49% to 73% in dwellings throughout North East Victoria. This Option also reduces wastewater discharges from dwellings by 45% to 75% and stormwater runoff from allotments by 3% to 38%.

The RWH Option incorporates the WEA Option. This Option reduces the water cycle impacts of buildings throughout the region. Different rainfall regimes across the region create greater variation in stormwater runoff and rainwater harvesting.

A combination of the WEA Option and reuse of wastewater for toilet and outdoor uses in the WWR Option reduced water demands and wastewater discharges throughout the region. The variation in reductions in water demands and wastewater discharges is a response to the different water use behaviours across the region.

The IWCM Option includes rainwater harvesting, wastewater reuse and the WEA Option. This Option produces considerable reductions in water demands, wastewater discharges and stormwater runoff that will provide multiple benefits for the region. Small changes in the components in this Option can further reduce the water cycle footprint of towns throughout the region.

The variation in the reductions in water demands, sewage discharges and stormwater runoff throughout the region are created by the different magnitudes of indoor and outdoor water demands, the variations in the depth and frequency of rainfall.

The impact of the low and high emissions climate change scenarios on the water balances in the Options is presented in Table 6.8.

Table 6.8: Impact of the climate change scenarios on the BAU Option

Location	Rainwater harvesting (%)		Stormwater runoff (%)		Outdoor water demand (%)	
	LE	HE	LE	HE	LE	HE
Beechworth	-0.8	-1.6	-15.5	-25.5	+3.9	+3.8
Bright	-0.3	-0.6	-13.2	-21.9	+3.9	+7.5
Chiltern	-0.8	-1.6	-15.5	-25.5	+3.9	+3.8
Wangaratta	-2.5	-4.8	-17.8	-28.7	+3.9	+7.3
Wodonga	-1.6	-2.8	-17.0	-28.1	+3.9	+7.2

Table 6.8 reveals that the climate change scenarios generated insignificant reductions in the yields from rainwater harvesting, considerable reductions in stormwater runoff and small increases in outdoor water use.

6.6 Regional results

The performance of the Options across the entire region in 2050 is provided in Table 6.10.

Table 6.10: Performance of the Options in the Wodonga East zone by 2050

Criteria	Reduction (%) for Option			
	WEA	RWH	WWR	IWCM
Demand for reticulated water	16.5	29.7	24.2	45.6
Wastewater discharges	12.1	12.1	26.7	35.7
Stormwater runoff	0	18.6	0	19.3

Table 6.10 reveals that adoption of the Options for all new and redeveloped buildings throughout North East Victoria will provide considerable reductions demands for reticulated water supplies and wastewater discharges.

6.7 Case Studies

Tallangatta

This case study to examined the water cycle benefits, economic and financial viability of the proposed *Tallangatta Tomorrow* [28] and the *Zero Energy Neighbourhood* [29] strategies. The timely provision of stormwater harvesting and facilities will ensure that the town of Tallangatta transitions to an exemplar for sustainable water management.

Tallangatta Tomorrow

Towong Shire Council has worked with the local community to develop the Tallangatta Revitalisation Strategy. A key objective of the strategy, known as 'Tallangatta Tomorrow', is to help Tallangatta become a thriving town. The project has set goals and initiatives that will be developed over the next 5 to 15 years with some projects that were identified as priorities for the shorter term. All projects are intended to make sure that Tallangatta is a prosperous town:

- where people of all ages want to live
- that has employment opportunities
- which supports the community with a range of community services
- that people are proud to call home
- where people can be part of a vibrant community
- which has a proud history and a bright future
- that includes exemplar sustainablility neighbourhoods

[28] Towong Shire Council (2011). Tallangatta revitalisation strategy. Tallangatta tomorrow – Tallangatta planning for growth. Report by One Collective.
[29] One Collective (2011). ZEN – zero energy neighbourhood. Report for Towong Shire Council.

The Tallangatta Tomorrow strategy includes the use of constructed wetlands and stormwater harvesting to reduce pollutant loads discharging to Lake Hume. After being treated at a Stormwater Treatment Plant, stormwater will substitute some potable water uses at the existing golf course, the caravan park, school buildings and ovals, sporting precincts and the Zero Energy Development.

The availability of an alternative water source will significantly reduce potable water demand and improve the amenity of the Tallangatta township.

ZEN – 'Zero Energy Neighbourhood'

Located in north east Victoria, approximately 40 kilometres south-east of Albury-Wodonga, Tallangatta is a township of approximately 1,000 residents situated on the edge of Lake Hume (see Figure 6.3). The township has experienced declining residential, business and tourism conditions over recent years. Towong Shire Council recently initiated the 'Tallangatta Tomorrow' program to investigate revitalisation opportunities for the town. In response to the outcomes of the community consultation and master planning process, a series of key projects have been identified for delivery, including the development of a new Zero Energy Neighbourhood (ZEN) using best practice sustainability and community design principles.

Figure 6.3: Aerial Photo of the township of Tallangatta

The ZEN development includes 48 allotments and 87 dwellings. The provision of rainwater tanks and solar panels in new developments is mandated in Council's planning policies. All detached dwellings within the development will incorporate a rainwater tank with a minimum capacity of 10,000 litres to capture rainwater for non-potable demands and reduce stormwater runoff. All homes within ZEN will also provide a 1 kW solar energy system for every 100 m^2 of floor space. The location of the ZEN development is presented in Figure 6.4.

Figure 6.4: Location of the Zero Energy Neighbourhood

Existing Water Cycle Systems

Water services in Tallangatta are provided by North East Water.[30] Water is sourced directly from Lake Hume and is treated using a DAFF (Dissolved Air Floatation and Filtration) treatment plant before distribution to the town. In 2005, the plant serviced 528 connections with an average annual residential water demand of 290 kL per house. The annual residential and commercial water use of the town is 224 ML. The existing water supply network is shown in Figure 6.5.

[30] North East Water (2007). Water supply – demand strategy. Delivery system plan. Tallangatta

Figure 6.5: Existing Water Supply System (North East Water)

The town's wastewater is pumped to a treatment plant south of the town, where it undergoes tertiary treatment before being reused for irrigation at a nearby agricultural site.[31] The treatment plan includes an 80 ML winter storage and ensures year round availability of water for reuse as shown in Figures 6.6 and 6.7.

The Tallangatta wastewater treatment plant is located approximately one kilometre south of the township and includes aging mechanical components including manual raked bar screens; A grit chamber; A primary sedimentation tank with a capacity of 129 m^3; A sludge digester tank; A low rate trickle filter; A maturation pond with a capacity of 1.1 ML and a winter storage of 80 ML

- The tertiary treatment elements of the plant are currently offline and the wastewater network in the township is subject to overflows and a high level of stormwater infiltration.

[31] North East Water (2010). Tallangatta wastewater system plan. Final Report

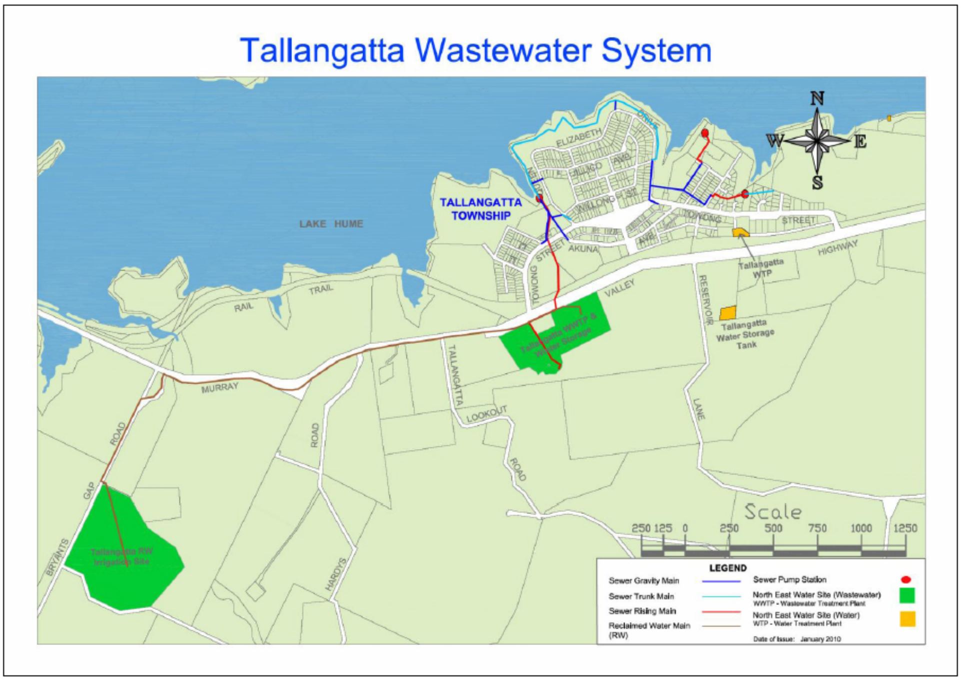

Figure 6.6: Existing Wastewater System

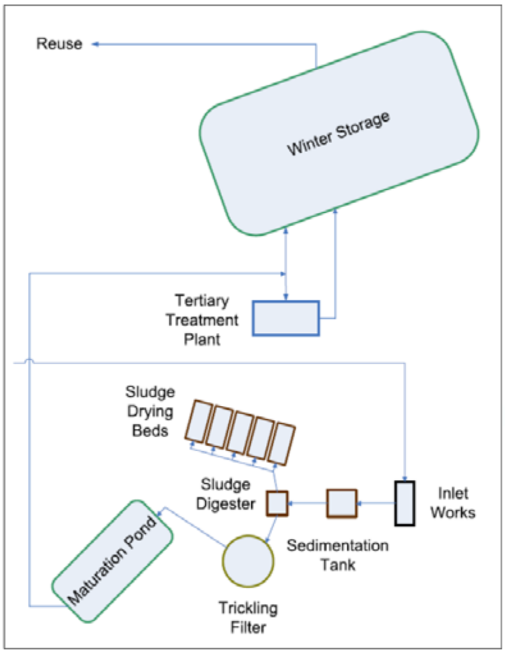

Figure 6.7: Existing wastewater treatment plant

Project Goals

The objectives of the ZEN stormwater harvesting project include:

- Protection of Hume Reservoir from stormwater and wastewater pollution
- Stormwater harvesting to supply non-potable water uses including in the ZEN development, local ovals, parks, schools, the golf course and caravan park.

Strategy

An agreed key objective for Tallangatta is to achieve energy and water sustainability in order to enhance the amenity of the town.[32] The strategy includes the use of water sensitive streetscape measures, and constructed wetlands and stormwater harvesting ponds as shown in Figure 6.8.

Figure 6.8: Diagram of the proposed stormwater harvesting and wastewater reuse strategy

Figure 6.9 provides the configuration of the stormwater treatment train.

[32] Tallagatta Tomorrow (2011). Community consultation

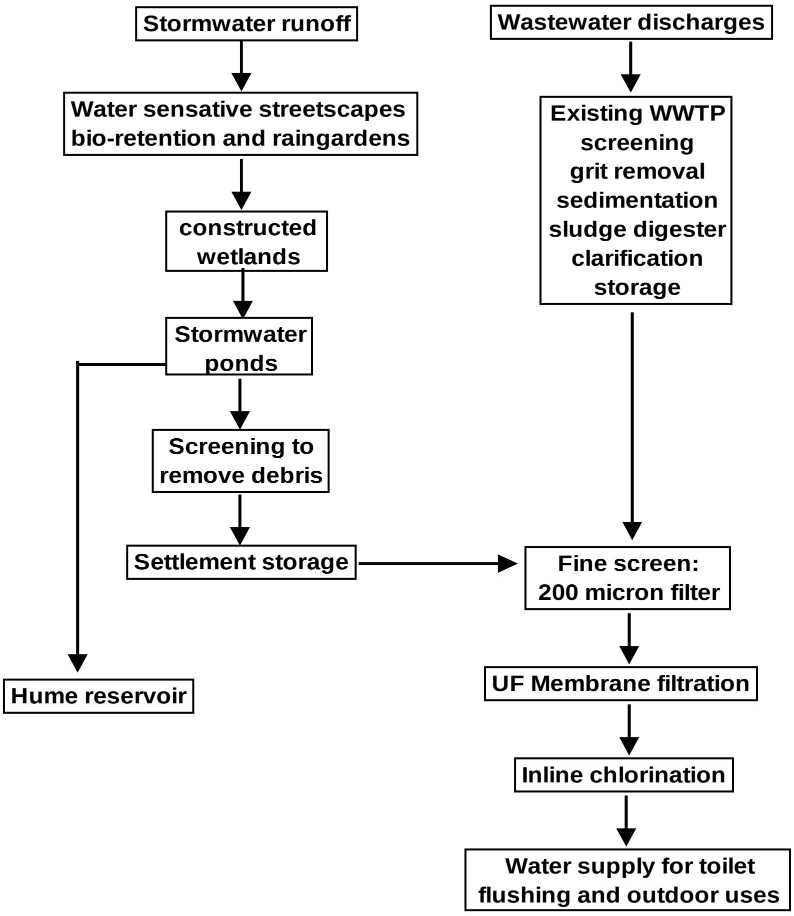

Figure 6.9: Configuration of alternative water sources in this project and the treatment train

Figure 6.8 and 6.9 illustrates that stormwater is captured from Tallangatta's urban impervious surfaces after passing through water sensitive streetscapes that include bio-retention and rain gardens. Stormwater is collected in three constructed wetlands adjacent to Hume Reservoir within the township of Tallangatta (Wetland A, B and C). The stormwater passes through the wetlands into stormwater storage ponds that apply filtration, settlement and screening prior to transfer to a water treatment plant.

Stormwater is distributed via windmills (or pumps in periods of insufficient wind) into a settling storage at the highest point in the vicinity of the town near the existing wastewater treatment plant. The use of windmills significantly reduces the energy requirements to transfer the stormwater. Transfer of stormwater to a high point avoids pumping later in the strategy.

Stormwater is then treated at a purpose built stormwater treatment plant using fine screening, UF (ultra-filtration) membrane filtration and inline chlorination. The treated water is transferred to a pressure reservoir for distribution via gravity for use in Tallangatta. The gravity fed system does not require additional pumping to distribute the water throughout Tallangatta.

Treated stormwater is used at key locations including schools, the sporting grounds, golf courses, the caravan park, public open space and the ZEN development. This strategy provides the necessary trunk infrastructure to facilitate future connections to the stormwater network.

Figures 6.8 and 6.9 also illustrated secondary treated wastewater from the existing wastewater treatment plant serves as a back up for stormwater during periods of lower rainfall. During periods of stormwater shortages, treated wastewater will supplement the stormwater supply. Rainwater harvesting also provides additional water to supply stormwater supply within the ZEN development. It is necessary for successful integrated water management strategies to have the diversity, resilience and flexibility of multiple water sources to ensure reliability and security.

Methods and results

The hydrology and water quality of stormwater discharging from catchments that impact on the project were analysed using the MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model for the existing and developed site. The project was analysed using the long continuous (6 minute) rainfall (1955 to 2011) and PET records from the Hume Reservoir station (Site number: 72023) sourced from the Australian Bureau of Meteorology.

The urban stormwater catchments in the town of Tallangatta (shown as catchments A, B and C in Figure 6.10) were defined using topography provided by the Towong Shire Council and the Department of Sustainability and Environment.

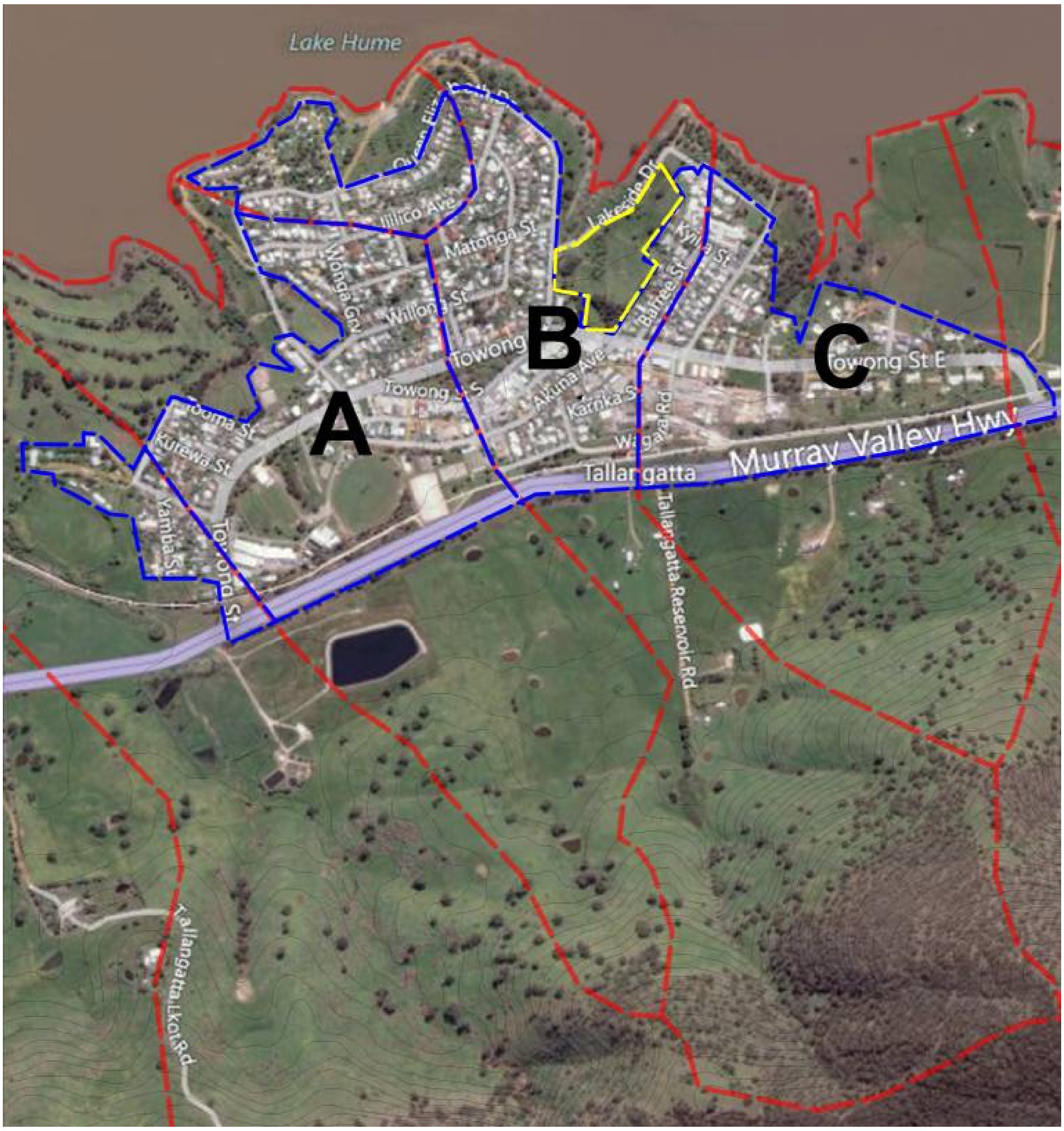

Figure 6.16: Stormwater catchments that impact on the Tallangatta

Figure 6.10 reveals that stormwater originates urban catchments and rural areas prior to discharging into the Hume Reservoir. The characteristics of the stormwater catchments used in the analysis are provided in Table 6.9.

Table 6.9: Stormwater catchments impacting on the Tallangatta project

Catchment	Catchment areas (ha) impacting on the project		
	Urban	Rural	Total
A	57.8	99.2	157
B	42	129	171
C	14.1	7.9	129

Stormwater runoff is harvested from the urban catchments whilst stormwater from the rural catchments discharge into Lake Hume.

The average annual water demands for detached housing of 290 kL/yr sourced from reports published by North East Water were employed in this investigation.[33] Outdoor water demands of 12 mm/week was defined for sporting ovals, the golf course, domestic gardening and public open space.[34] The demands for stormwater harvesting in this project are presented in Table 6.10.

Table 6.10: Demands for stormwater harvesting

Location	Description	Water demand (ML/yr)	
		Outdoor	Indoor
ZEN	48 lots	4.1	7.1
Tallangatta Secondary School	485 people	-	0.6
Tallangatta Primary School	138 people	2.2	0.2
St Michael's Primary School	40 people	2.6	0.1
Caravan Park	85 sites	9.7	0.7
Sporting Complex		5.0	0.1
Golf course		54.3	0.1
Showgrounds		8.0	-
Memorial Park		2.5	-
Tallangatta Triangle		3.6	7.1
Total		**92**	**8.8**

The demands for harvested stormwater shown in Table 6.10 were employed in the hydrological simulations to determine the viability of the proposed strategy.

In addition, the financial and economic viability of the strategy was evaluated using a 9% discount rate and a 20 year horizon. It was assumed that the management and costs of stormwater management and the wastewater reuse systems accrue to public authorities. The management and associated costs of rainwater tanks and solar panels are borne by the developer in accordance with Council policy. It is likely that

[33] North East Water (2007). Water supply – demand strategy. Delivery system plan. Tallangatta
[34] Towong Shire Council (2007). Towong Shire Council recreation strategy.

Towong Shire Council will be the developer of the Zen Development. The following costs were considered in the analysis:

- The initial capital investments were allocated over 20 years
- Annual operation and maintenance costs to support the new infrastructure
- Periodic replacement costs within the 20 year horizon
- Residual value of the fixed investment (included as a benefit in the 20th year of analysis to reflect 21 to 100 years of capital investment planning) for physical assets with longer lifecycle.
- The benefits considered in the 20 year horizon include reduction in demands for mains water and associated revenue earned from tariffs for harvested stormwater, and the reduced pollutant loads discharging to Hume reservoir. Usage tariffs for mains water in the North East region of Victoria are currently $2.19/kL.

This analysis has also considered the deferred greenhouse gas emissions. Mains water supplied in the North East region produces 168 tonnes of greenhouse gas emissions (GHG) for each 1000 properties.[35] The reported average annual water use of 213 kL per property was used to derive the greenhouse gas emissions of mains water supply of 0.789 kg of GHG emissions per kL of water supplied. A carbon price of $23/tonne was assumed in accordance with recent government policy. The investigation also considered that benefits of reduced nutrients loads discharging to Lake Hume at a value of $2,550/kg.[36]

Harvested stormwater transferred to the stormwater treatment plant will be partially provided by windmills located at the 3 pond sites.[37] The proportion of water transfers that can be provided using wind power was determined using Bureau of Meteorology wind profiles from the Hume Reservoir weather station (Station number 72023 – length of record: 1965 to 2010). The efficiency and costs of the windmill pumps are shown in Table 6.11.

Table 6.11: Details of windmill pumps used for water transfers

Transfer	Max transfer (m^3/day)	Blade diameter (m)	Proportion of transfer (%)	Wind assisted transfer (ML/yr)	Cost ($)
C to B	44.2	2.44	59	26.1	13,440
B to A	88.4	6.1	56	49.5	33,110
A to WTP	133	6.71	59	78.5	34,310
Total					**80,860**

Table 6.11 reveals that the windmill pumps provide a pumping efficiency of about 59% at a total installed cost of $88,860. The costs of the back up pumps that are reliant on electricity are presented in Table 6.12.

35 NWC and WSA (2011). National performance benchmarking reports – urban water utilities.
36 Melbourne Water Corporation (2011). Submission to the Ministerial Advisory Council for the Victorian government's Living Melbourne Living Victoria policy.
37 Comet windmill and water products (2009). Retail price catalogue – traditional technology for modern energy needs.

Table 6.12: Details of back up pumps used for water transfers

Transfer	Max transfer (m^3/day)	Cost ($)
C to B	44.2	12,030
B to A	88.4	24,110
A to WTP	133	36,120
Total		**72,260**

Table 6.12 indicates that installation of back up pumps at each pond will site will cost $72,260. The details of the transfer conduits between the stormwater harvesting ponds and to the stormwater water treatment plant are provided in Table 6.13

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Table 6.13: Details of conduits used to transfer stormwater to the water treatment plant

Transfer	Length (m)	Diameter (mm)	Cost ($)
C to B	640	100	72,960
B to A	1390	100	158,460
A to WTP	970	100	110,580
Total			**342,000**

Table 6.13 reveals that the total costs of the conduits used to transfer stormwater to the stormwater treatment plant is $342,000. The details of conduits used to supply treated stormwater to a range of end uses within the Tallangatta township are presented in Table 6.14.

Table 6.14: Details of conduits used to supply treated stormwater wastewater to Tallangatta

Transfer	Length (m)	Diameter (mm)	Cost ($)
Treatment Plant to A	640	150	97,920
A to ZEN	1,580	150	241,740
Football facilities	380	100	43,320
Sporting precinct	350	100	39,900
Golf club	290	100	33,060
Schools	110	100	12,540
Total			**468,480**

Table 6.14 shows that the total costs of conduits supplying end uses in Tallangatta were $468,480.

A settlement and mixing tank with a capacity of 100 kL at a cost of $80,000 will be provided prior to the stormwater treatment plant. The treatment plant will include a 200 micron rolling drum screen, an ultra-filtration (UF) membrane plant, inline chlorination, pumps and remote monitoring systems at a cost of $635,000. Treated stormwater will be transferred to a new pressure reservoir with a capacity of 250 kL at a cost of $100,000.

Towong Shire Council have utilised local planning policy to mandate installation of solar panels in the ZEN development. The policy requires installation of solar panels to provide a minimum of one kW of solar energy for each 100 m^2 of floor area.

Council also mandates the use of 10 kL rainwater tanks to supply non-potable uses in all new developments. The cost to install 87 rainwater tanks at the ZEN development was $430,650.

Installation of a 1.5 kW solar system at each of the 87 dwellings in the Zen development will generate an energy saving of 179,733 kWh at an installed cost of $417,600. Using the translation factor of 1.23 provided by the Department of Climate Change and Energy Efficiency this results in an annual reduction in greenhouse gas emissions of 221,072 kg.[38]

The water balance from the simulations of the stormwater (and backup rainwater and wastewater) for non-potable use is provided in Table 6.15.

Table 6.15: Water balance for the stormwater harvesting and wastewater reuse project

Source	Supply volume (ML/yr)	Proportion of demand (%)
Rainwater harvesting	5	86
Stormwater harvesting	76	80
Wastewater reuse	19	100
Total	**100**	**99**

Table 6.15 demonstrates that the project will provide an annual average volume of 100 ML which is 99% of the demands for alternative water sources identified in this project. A small deficit in stormwater available from urban catchments was revealed that was supplemented using treated wastewater to produce 100% reliability. Note that the available supply from the urban stormwater catchments was considered to be the difference between urban stormwater runoff and expected environmental flows from a pre-urban catchment.

Importantly, the provision of the trunk infrastructure in this project will allow additional future opportunities for replacing mains water supplies with harvested stormwater.

The project budget is presented in Table 6.16. It is expected that the project can be delivered over a three year period.

[38] Department of Climate Change and Energy Efficiency (2010). National Greenhouse Accounts (NGA) Factors

Table 6.16: Project budget and timing

Item	Costs
Constructed wetlands	$1,109,481
Stormwater Harvesting Ponds	$711,981
Rainwater Tanks	$430,650
Back up pumps	$72,260
Transfer Mains	$342,000
Supply Mains	$468,480
Plumbing connections	$120,000
Third pipe in ZEN	$120,000
Untreated water reservoir	$40,000
Treated water reservoir	$100,000
Stormwater treatment plant	$635,000
Windmills	$80,856
Solar panels	$417,600
Total	**$4,648,308**
Engineering Cost (Design and Supervision)	$232,415
Project management and supervision	$464,831
Physical and Price Contingencies	$464,831
Total Project Cost	**$5,810,385**
GST	$581,039
Total Project Cost (with GST)	**$6,391,424**

Table 6.16 collates the project budget that was used in the economic and financial analysis of the project. The proposed stormwater harvesting project will be subject to ongoing operating and maintenance as shown in Table 6.17.

Table 6.17: Operating, maintenance and renewal costs of the project

Item	Costs ($/yr)
Water testing	30,000
Power	1,800
Chemicals	1,750
Operator (416 hours)	25,000
Operation and maintenance	77,277
Total	**135,827**

Table 6.17 reveals that the annual costs of operation, maintenance and renewals will be $135,827. These costs include contributions for water testing, chemicals, power and for an operator at the stormwater treatment plant. The operation and maintenance costs were derived as:

- 0.5% per annum for conduits and storages (design life is greater than 100 years)
- 2% per annum for constructed wetlands, ponds, rainwater tanks, stormwater treatment plants, windmills and solar panels (design life is 50 years)
- 5% per annum for pumps (design life is 20 years)

Note that the longer term economic and financial analysis of the project also includes periodic replacement of infrastructure in accordance with the design lives specified above.

The balance of greenhouse gas emissions for the project is provided in Table 6.18.

Table 6.18: Balance of greenhouse gas emissions of the proposed Tallangatta strategy

Item	Balance of emissions (kg/yr)	
	Generation	Reduction
Stormwater treatment plant	75,900	
Rainwater pumps	6,679	
Transfer pumps	6,563	
Solar panels		221,072
Deferred potable water		78,900
Total	**89,142**	**299,972**

Table 6.18 demonstrates that the project will provide greater reductions in greenhouse gas emissions than the emissions generated by the strategy. The project provides a net annual reduction in greenhouse gas emissions of 210,830 kg. These reductions translate to an annual value of $4,849. Note that energy use of the rainwater pumps and the stormwater treatment plant was 1,068 kWh/ML and 756 kWh/ML respectively.

The impacts of the stormwater harvesting strategies on the quality of stormwater entering Hume Reservoir are presented in Table 6.19.

Table 6.19: The quality of stormwater generated by the proposed Tallangatta strategy

Criteria	Sources	residuals	Reduction (%)
Flow (ML/yr)	923	439	52
Total suspended solids (kg/yr)	142,000	6,270	95.6
Total phosphorus (kg/yr)	349	32.7	90.6
Total nitrogen (kg/yr)	2,540	537	78.8
Gross pollutants (kg/yr)	27,300	0	100

Table 6.19 reveals considerable reductions in the pollutant loads discharging into Lake Hume whilst maintaining the expected average annual environmental flows into the Lake of 439 ML. The value of the reduction in the nitrogen load was $5,117,665.

Economic and financial viability

A key objective of the project is to replace current and future potable water supply with harvested stormwater for the community of Tallangatta. In addition the project aims to reduce nutrient loads discharging to Hume Reservoir and to decrease greenhouse gas emissions.

The proposed investment will be of a public sector nature. All benefits will flow to the local, regional and State populations. As such, an investment analysis completed for this project was mostly an economic investigation. Issues such as the cost recovery of annual operating and maintenance costs (typically a financial issue) have also been addressed. The residual (or salvage) value or financial value of the assets after 20 years has also been included.

An economic analysis has been completed using DTF/COAG Investment Guidelines. All component costs and benefits have been estimated using 2011 values. All taxes and the GST component have been excluded. The economic benefits have been estimated at the local, regional and State of Victoria level. It is assumed that all benefits accrue to the public sector and are based on better management of resources. A 20 year planning horizon has been assumed with 3 years allocated for development and commissioning. All benefits begin in Year 4.

The overall economic and financial viability of the project has been estimated in an analysis that includes investment by Towong Shire Council and seed funding from other entities of $3.2 m (such as government departments or grant funding). The project is viable with:

- an economic internal rate of return (IRR) of 46%, and
- a net present value (NPV) of $4.096 million.

This result demonstrates that the capital, and operating and maintenance cost commitments of the project can be fully serviced for the duration of the project time period.

Wodonga

Water supply for the Wodonga district is extracted from the Wodonga Creek, an anabranch of the heavily regulated Murray River, downstream of Lake Hume. The Murray River is fed by the Kiewa River and the Mitta River via Lake Hume. Lake Hume has a full supply capacity of 3,005 GL. Raw water is pumped 3.5 km from Wodonga Creek via five pumps to a 32 ML raw water storage (of which 8 ML is dead storage) located at the Wodonga Water Treatment Plant.

The Wodonga water distribution network has been progressively extended over past years. Locations serviced from the Wodonga extraction and treatment systems include Wodonga, Barnawartha, Chiltern, Springhurst, Baranduda, Kiewa and Tangambalanga. The performance of the water cycle in the District was analysed for the period 2010 to 2050. A schematic of the Wodonga system is provided in Figure 6.17.

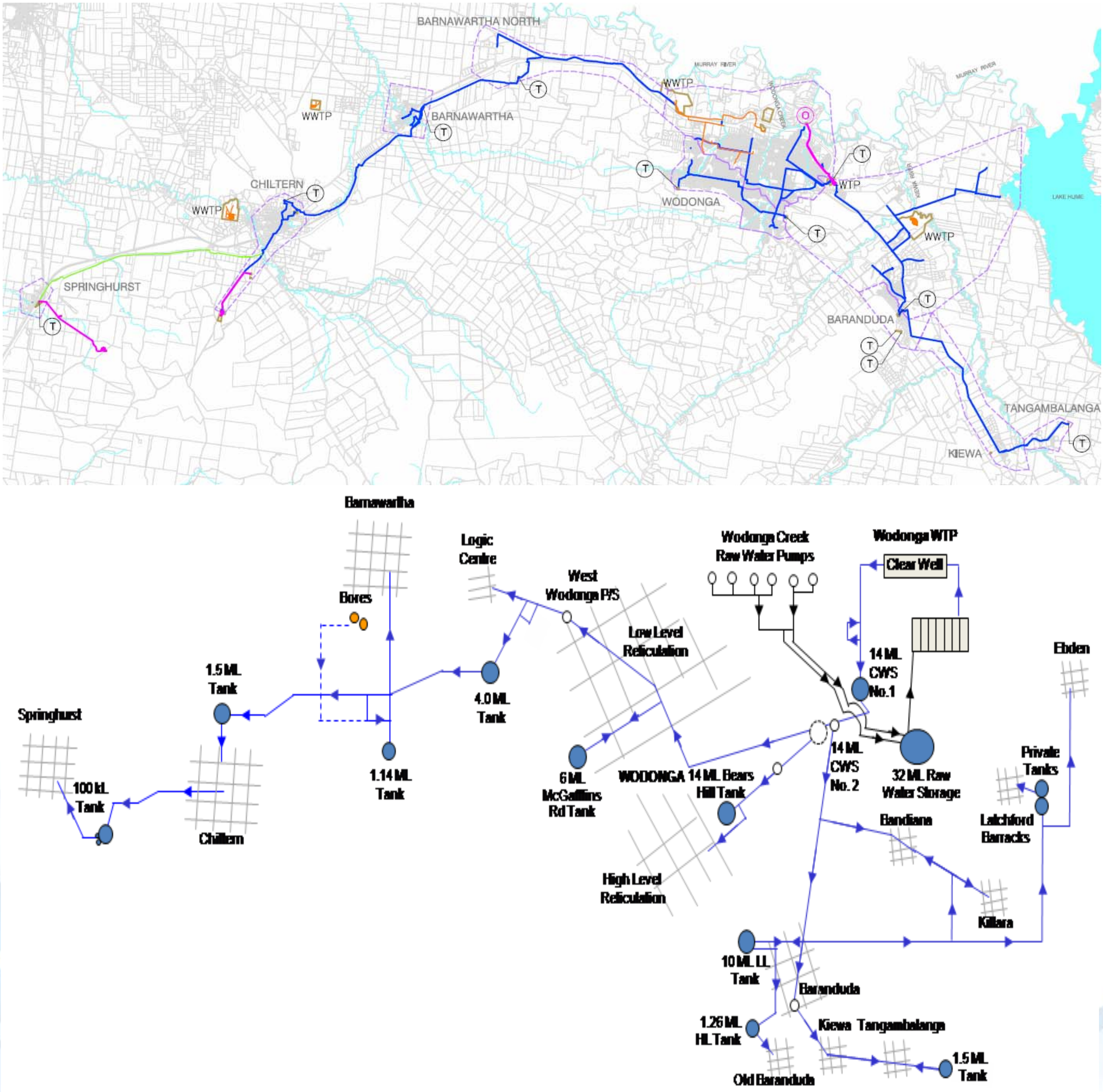

Figure 6.17: Schematic of the Water Supply for the Wodonga District (North East Water)

Specific issues relating to the Wodonga water system are:

- High population growth rate predicted
- Additional demand if Logic Centre expands significantly, which will require increase in Wodonga cross town transfer capacity for supply to pipeline towns (i.e. Barnawartha, Chiltern and Springhurst)
- System losses are about the same as the industry standard
- Geographically dispersed distribution system resulting in high pumping costs

The water demands for the Wondonga Water district for the BAU, WEA and RWT Options are presented in Figure 6.18.

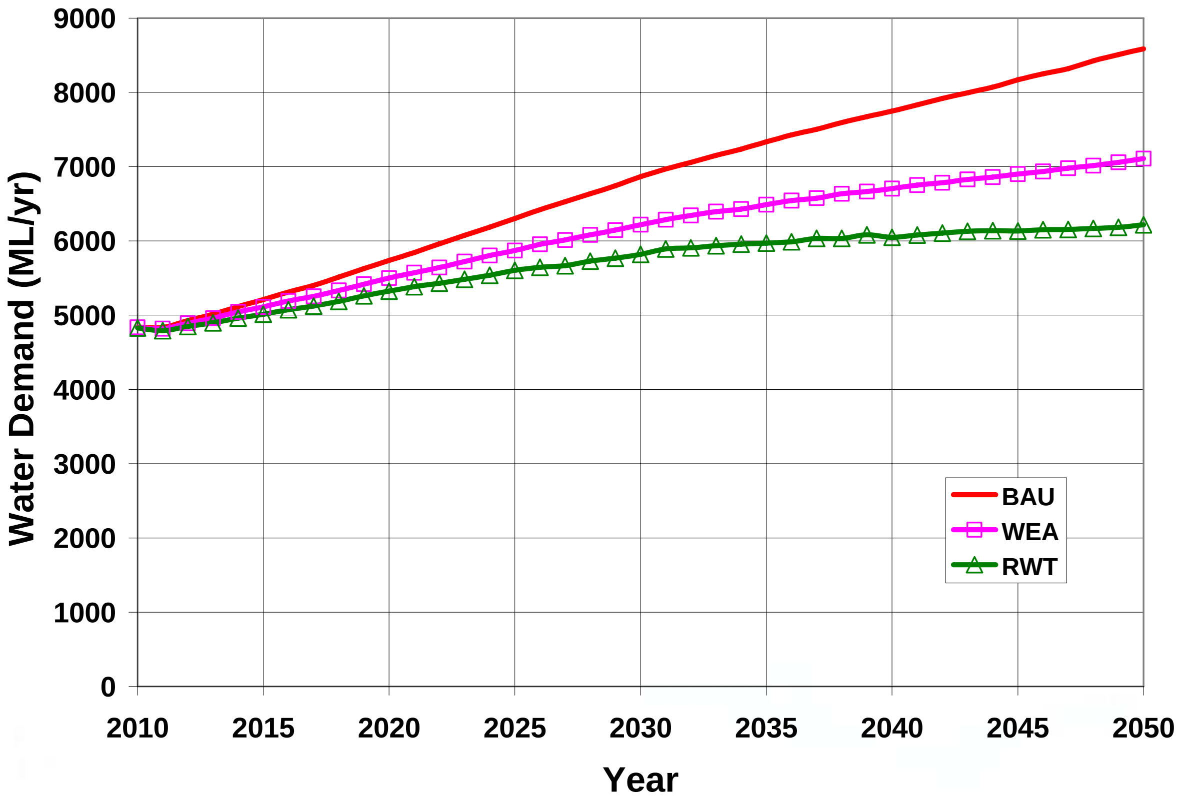

Figure 6.18: Water demands for the Wodonga District

Figure 6.18 reveals that the WEA and RWT Options generate significant reductions in water demands within the planning horizon of 19% and 29% respectively. It is noteworthy that it is unlikely that Wodonga District will exceed the current water license allocation of 13,175 ML/annum.

The water demands for the planned Leneva urban growth area for the BAU, WEA and RWT Options are presented in Figure 6.19.

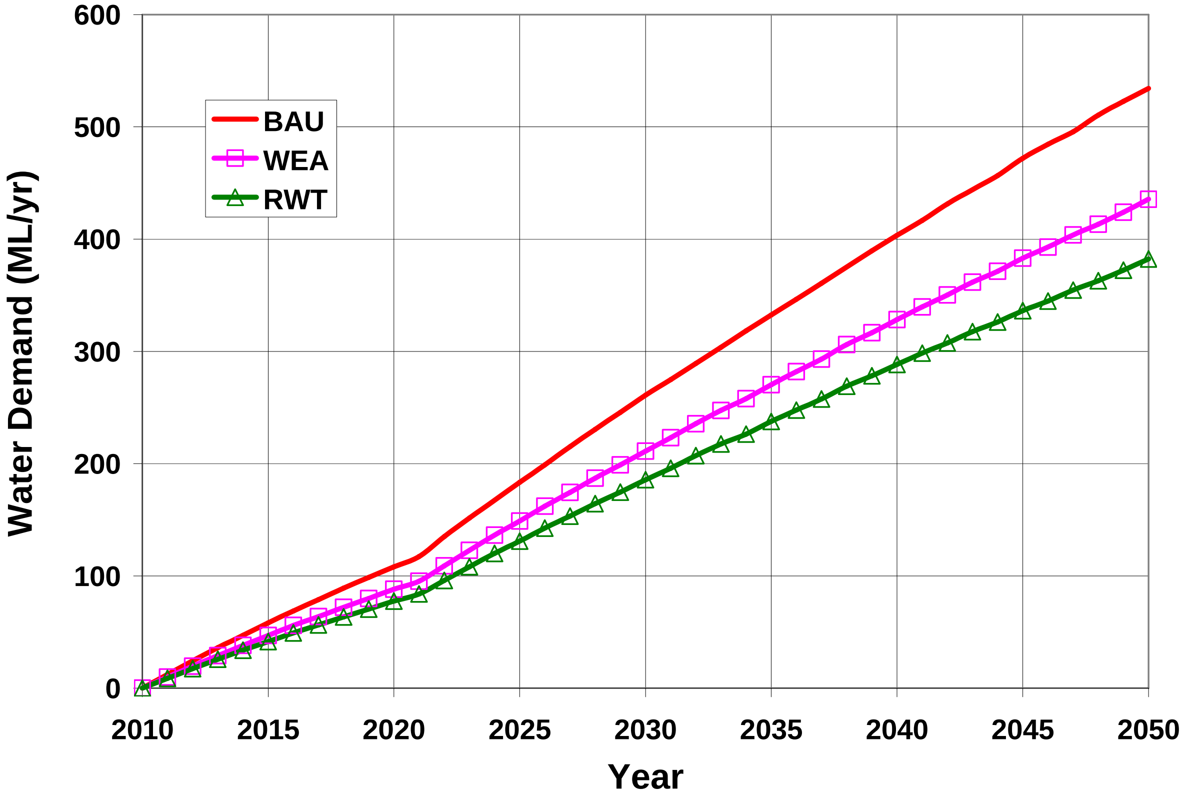

Figure 6.19: Water demands for the Leneva urban growth area

Figure 6.19 reveals that the WEA and RWT Options generate reductions in water demands for the Leneva urban growth area within the planning horizon of 19% and 29% respectively. The Leneva area is subject to substantial growth in water demands that is consistent with an urban growth corridor.

The wastewater discharges for Wodonga City for the BAU, WEA and RWT Options are presented in Figure 6.20.

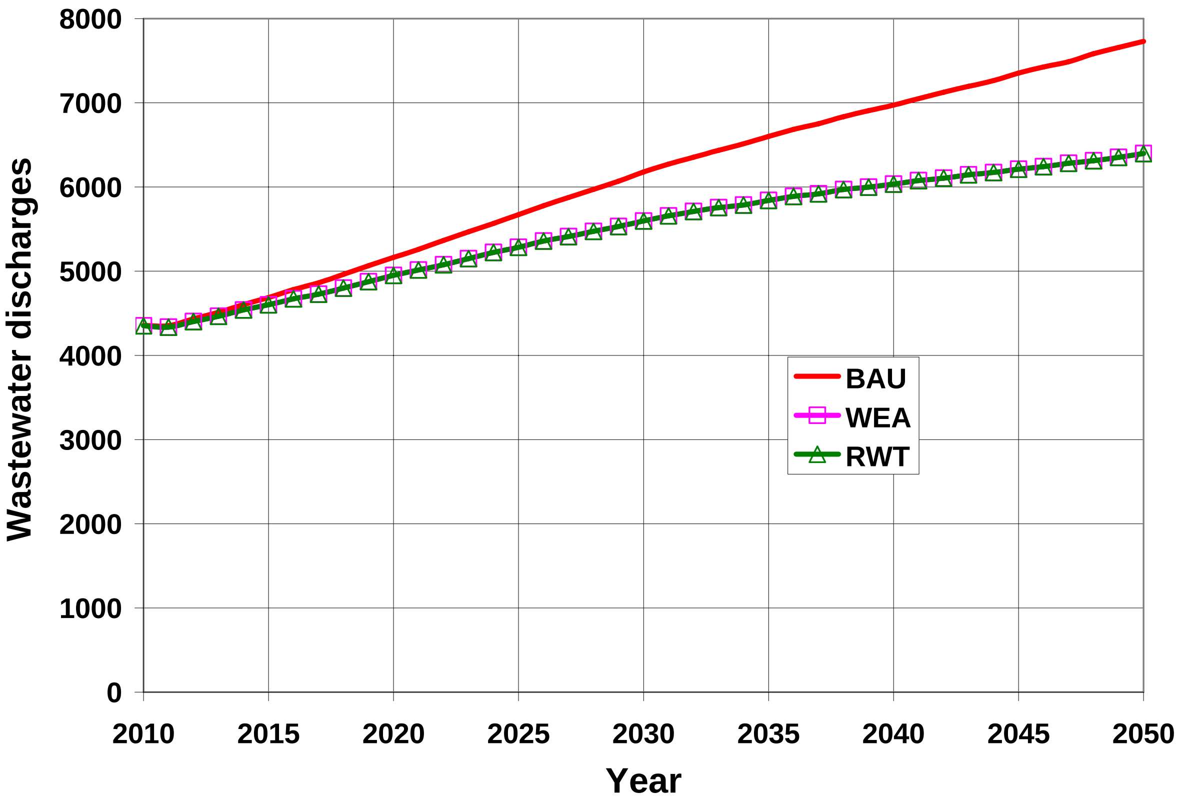

Figure 6.20: Wastewater discharges for Wodonga City

Figure 6.20 demonstrates that the WEA Option also reduces wastewater by up to 17% within the planning horizon.

The wastewater discharges for the Leneva urban growth area for the BAU, WEA and RWT Options are presented in Figure 6.21.

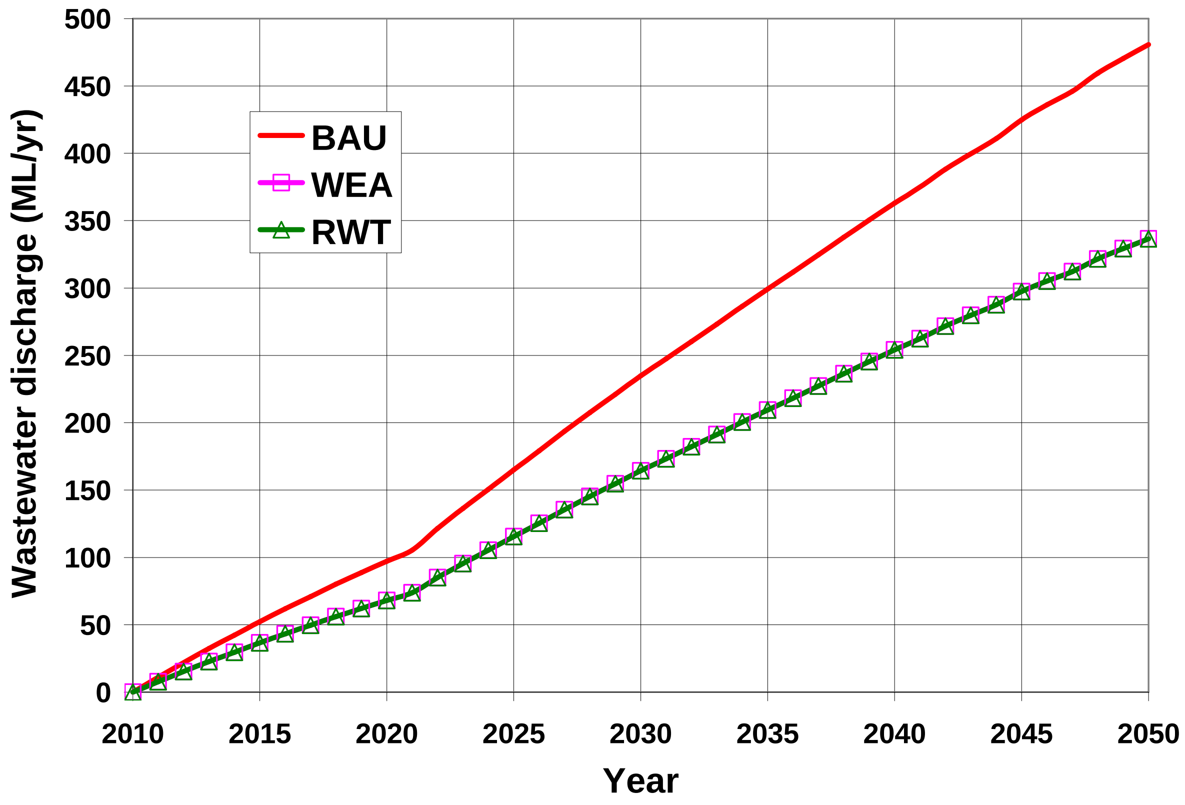

Figure 6.21: Wastewater discharges from the Leneva urban growth area

Figure 6.21 reveals that the WEA Option provides considerable reductions in wastewater discharges of 30% in the Leneva urban growth area. This result provides an indication of the potential for reducing water demands and wastewater discharges in a new urban growth corridor.

7 Conclusions

A forensic analysis has been undertaken of the existing biophysical systems that are related to North East Victoria. The analysis incorporates inputs from many disciplines, to understand the potential futures of towns in the region.

The existing sophisticated integrated systems models of the North East region developed by Dr Peter Coombes have been updated and enhanced for use in this project. These models subdivide the region into hierarchies of distributed nodes, or 'zones', that represent opportunities, constraints and feedback loops across multiple scales. A selection of indicative alternative Options; WEA, RWH, WW and IWCM; were compared to the business as usual (BAU) Option to understand the response of the North East Victorian system to alternative strategies. The alternative Options considered in this investigation are:

WEA – this Option includes water efficient buildings, gardens and practices and rainwater in all new and redeveloped buildings.

RWH – this Option combines the WEA Option with rainwater harvesting to supply laundry, toilets and outdoor uses in all new and developed buildings.

WWR – this Option combines the WEA Option with wastewater reuse to supply outdoor uses in all new and developed buildings.

SWH – this Option combines the WEA Option with stormwater harvesting to supply toilets and outdoor uses in all new and developed buildings.

IWCM – this Option combines the WEA Option with wastewater reuse for toilet and outdoor uses with rainwater harvesting to supply the remaining indoor water uses in all new and developed buildings.

The analysis revealed that annual rainfall is highly variable over time and throughout North East Victoria. It is also clear that the region has not been subject to a “step change” in rainfall regimes.

The climate change scenarios modelled generate moderate reductions in average annual rainfall and large reductions in streamflow in rivers by 2050. This result indicates that the availability of regional water resources will be dramatically diminished by 2050.

Climate change scenarios generated insignificant reductions in the yields from rainwater harvesting, considerable reductions in stormwater runoff and small increases in outdoor water use.

There is sufficient depth of annual rainfall, even during low rainfall years, for significant rainwater and stormwater yields at all locations throughout North East Victoria.

A summary of the results of this study is presented below:

7.1 Climate

- The recent drought reduced average annual rainfall by 4.8% to 19.5% throughout North East Victoria and included a 4% (0.9°C) increase in average daily maximum temperatures.
- Increases in temperaure and evaporation with reduced rainfall in the recent drought reduced annual average streamflow in rivers by 16.5% to 37.9%.
- The recent drought may not be the worst period of low rainfall on record at many locations throughout North East Victoria and is consistent with the cycles of natural variation in rainfall.
- The rainfall records in the North East region do not reveal evidence of a step change in rainfall regimes.
- The region is subject to a high frequency of rainfall events (on average, every 3 to 6 days) and is eminently suitable for highly efficient rainwater and stormwater harvesting strategies.
- Climate change may generate reductions in annual average rainfall of 9% to 18% and diminish annual average streamflows by 25% to 45% by 2050. It is noteworthy that these scenarios produce years with very low flows in the regions rivers that is consistent with more severe droughts.

7.2 Lot Scale Analysis

- Although climate change generates large reductions in average annual streamflows in rivers, the average annual yields from rainwater harvesting was insignificant ranging from 0.3% to 4.8%. In constrast reductions in stormwater runoff ranged from 13.2% to 28.7%. Local strategies were resilient to the impacts of climate change.

- Climate change also generated small increases in outdoor water use ranging from 3.9% to 7.5%.
- Water efficient buildings, gardens and practices reduces demands for reticulated water by 31% to 34% and decreases wastewater discharges by 25%.
- Rainwater harvesting with water efficient buildings, gardens and practices generated considerable reductions in water demands (58.9% to 64%) with diminished wastewater discharges (25%) and stormwater runoff (17% to 45.4%).
- Wastewater reuse with water efficient buildings, gardens and practices generated significant reductions in water demands (41.1% to 52.3%) with diminished wastewater discharges (38.7% to 53.7%).
- A combination of rainwater harvesting and wastewater reuse with water efficient buildings, gardens and practices can produce “water independent households” throughout the region. This integrated water cycle management (IWCM) Option generated large reductions in demands for reticulated water supply (93.1% to 99%) with substantially diminished wastewater discharges (63% to 73%) and reductions in stormwater runoff (18% to 48%).
- The internal water resources within North East Victoria that can be derived from water efficiency, rainwater, stormwater and wastewater are greater than the demands for urban water supplies.

7.3 Regional analysis

- Adoption of water efficent buildings, gardens and practices in all new and redeveloped buildings throughout North East Victoria will provide reductions in water demands and wastewater discharges by 16.5% and 12.1% respectively in 2050.
- Use of the RWH Option in all new and redeveloped buildings generates reductions in water demands (29.7%), wastewater discharges (12.1%) and stormwater runoff (18.6%) by 2050.
- Use of the WWR Option for all new and redeveloped buildings creates reductions in water demands (24.2%) and wastewater discharges (26.7%) by 2050.
- An IWCM Option for all new and redeveloped buildings generates reductions in water demands (45.6), wastewater discharges (35.7%) and stormwater runoff (19.3%) by 2050.
- The IWCM Option will mitigate the “worst case” impacts of future climate change on urban water resources throughout the region and the remaining Options will siginficantly diminish the impacts of expected climate change.
- More rapid rates of adoption for any of the Options will produce greater water resources benefits to the natural limits demonstrated by the lot scale results in items 9 to 12 above.

6.4 Strategies for Implementation, (Leadership and Community Engagement)

- More rapid rates of adoption of alternative Options will produce greater water resources benefits to the natural limits demonstrated by the lot scale results in items 9 to 12 above.

- Councils and all agencies can demonstrate community leadership by ensuring that all future projects include water security objectives in their decision making.
- Councils in particular should ensure that this document does not become lost in the archives but continues to be a valuable source document informulating policies for building and development.
- Councils should ensure that future Planning Schemes, particularly the Municipal Strategic Statements and Local Planning Policy Frameworks provide the catalyst for early adoption of the above findings.
- Councils should develop engagement strategies to ensure that the findings of this report are implemented at the Lot Scale and across the wider community.
- Councils, DPCD and North East Water should work together to ensure that the water security measures detailed in this report are considered in all future planning scheme rezoning, and major developments.
- Strategies to encourage community acceptance, implementation and adoption will be required. This will require good leadership and governance, good community engagement and respected local champions.
- North East Water should ensure that future Water Supply Demand Strategies are cognizant of the findings of this report and promote these water security measures.

Adoption of the above findings and recommendations should ensure that:

- The right quality water is used for appropriate uses.
- The community and agencies value their water resources.
- That water conservation measures ensure that water is available for community assets and amenity, particularly in times of reduced rainfall.
- Social amenity is maintained and enhanced.
- The community understands the differences between water conservation and water restrictions.
- The community recognises its unique position, high in the catchment, and is cognisant of both the quality and quantity of water available for downstream communities dependant on this resource.