A study into the supply, demand, economic, social and institutional aspects of optimising water supply to metropolitan Adelaide – preliminary research findings: Summary report from Project U2.2

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1 Introduction

In November 2012, the Goyder Institute for Water Research funded a research programme as a contribution to the building of a strong information base to inform debate on how best to underpin an efficient and sustainable water supply for metropolitan Adelaide, now and into the future, due to the likely impacts of a drying climate and population growth. Metropolitan Adelaide has multiple sources of water – surface water, groundwater, desalinated water, stormwater, roof or rain water, recycled water and the River Murray – that can be utilised and managed for supplying the city's water needs. Using those sources in combination requires consideration of an appropriate balance across objectives such as supply security, economic cost, social preferences and environmental impacts. The research programme, project U2.2 within the Goyder Institute for Water Research's urban water portfolio, was designed to explore these considerations through:

- engaging with stakeholders to provide an effective communication pathway and an agreed basis for evaluating alternative water supply mixes
- providing a model that simulates the supply, demand and stormwater and wastewater discharge dynamics of Metropolitan Adelaide water supply system
- developing a multi-objective optimisation methodology to assess trade-offs
- monitoring household water use to better predict demand
- performing legal and governance analysis in delivering water solutions
- conducting economic analysis of the direct and indirect costs of supplying water from the multiple sources
- improving understanding of social values and preferences regarding water solutions.

The project team was drawn from researchers at the Universities of Adelaide and South Australia, Flinders University, CSIRO and SA Water, with contributions from EPA, the SA Departments of Environment, Water and Natural Resources; and Planning, and the Adelaide and Mt Lofty Ranges Natural Resources Management (AMLRNRMB). The project concluded in early 2014.

The purpose of this report is to provide a summary of this research and its preliminary research findings, and how those findings may be used to inform discussion about managing the city's water now and into the future. The contents of this report are drawn from the suite of material written by the project team to report the details of their investigations.

1.1 Water sources

The project considered seven water sources and demand management (water efficiency and reduced demand) for a range of potable and non-potable purposes:

- supply from the Mount Lofty Ranges catchments
- pumping from the River Murray
- desalinated seawater
- groundwater
- harvested stormwater
- recycled wastewater
- roof or rainwater captured in rainwater tanks
- demand management, including various household appliances.

Detailed descriptions of these sources and demand management, agreed by the project team with its stakeholders, are provided in Appendix B .

1.2 Integrated urban water management (IUWM) decision support framework

To bring together all the necessary components to evaluate and select optimal mixes of water sources for cities and towns required the development of an integration framework. This framework uses a systems analysis approach, taking into account technical, economic, environmental and social factors to assess combinations of traditional and alternative water sources. When applied to planning studies, this approach incorporates IUWM principles such as minimising usage of resources to provide urban water services (e.g. fresh water, energy, materials); minimising wastes generated from the urban water system through recovering resources from wastes; enhancing liveability by providing acceptable levels of service; and improving the wellbeing of ecosystems.

The IUWM DSF comprises eight components (Figure 1):

1. **Identify overall goals**, i.e. identifying the purpose of applying the IUWM DSF. For example, for this study, the purpose of applying the IUWM DSF was to inform policy questions related to the development of an Urban Water Blueprint or IUWM Plan for Metropolitan Adelaide, e.g. what are the most cost effective, environmentally sustainable and socially acceptable water supply sources to meet current and future demands of Metropolitan Adelaide?
2. **Formulate the problem**, i.e. formulating a problem to achieve the overall goal. For example, for this study, the problem could be defined as, how could different portfolios of water supply be evaluated to identify the optimal portfolio in terms of a set of defined objectives?
3. **Identify objectives, decision variables and constraints**, i.e. defining the objectives to measure the achievability of goals, identifying influencing variables of the objectives, and identifying the limits that defined the scope of problem
4. **Translate objectives and constraints into measurable criteria**, i.e. defining a metric (or set of metrics) to facilitate quantification of each objective (e.g. metrics related to the

objective on environmental sustainability could be energy consumption and discharge of stormwater and wastewater to receiving waters)

5. **Identify alternative options**, i.e. identifying the opportunities or options to improve the system in terms of the goals
6. **Evaluate alternative options in terms of the measurable criteria**, i.e. use of appropriate techniques to quantify the metric of each objective (e.g. hydrological modelling to quantify stormwater discharging to receiving waters)
7. **Identify the efficient options using multi-objective optimisation**, i.e. use of an appropriate optimisation technique (e.g. genetic algorithm and linear programming) to identify solutions that best meet the objectives
8. **Select preferred options**, i.e. selecting preferred solutions from a large number of optimal solutions (i.e. output of #7), considering preferences and values of stakeholders and using an appropriate technique such as multi-criteria analysis.

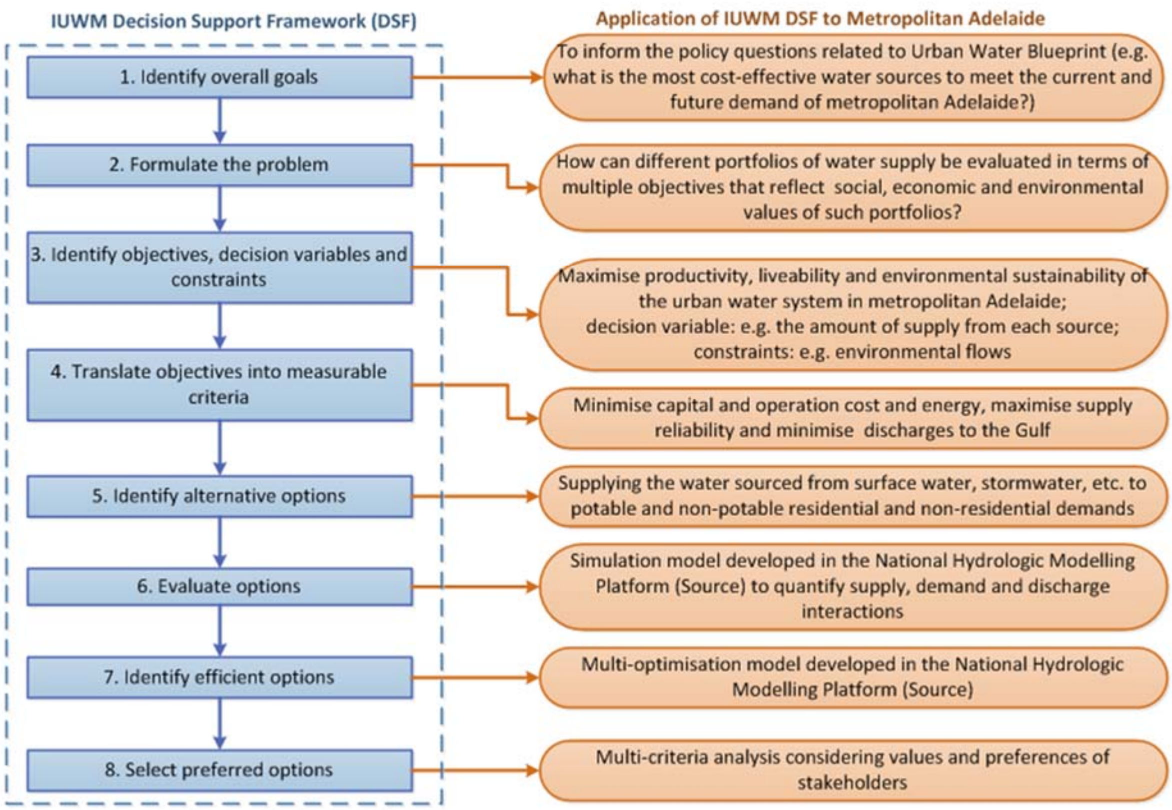

Figure 1 Key components of the IUWM decision support framework and a high level description of its application to the metropolitan Adelaide case study (figure sourced from Maheepala et al. (2014))

1.2.1 Metro Adelaide case study

Components 1–7 of the framework has been implemented as a proof-of-concept by applying it to a case study of metro Adelaide for 2013 (i.e. current), 2025 and 2050. Component 8 was not included in the project plan as determining values and preferences would require consideration of broader policy objectives and more extensive stakeholder engagement that were possible within the scope of this case study; and resources to design and implement a full multi-criteria analysis were also not available. This demonstration uses a combined simulation-optimisation approach to search for the solutions that best meet the agreed set of objectives. For this case study, objectives to assess the most cost effective, environmentally sustainable and socially acceptable mix of water sources to meet the water demands of metro Adelaide were workshopped in late 2012 with key stakeholders and are listed in Table 1, which also lists the constraints that must be met.

Table 1 Objectives and constraints to assess the most cost effective, environmentally sustainable and socially acceptable mix of water sources to meet the water demands of metro Adelaide

objective	type
minimise the total present value of the life cycle cost of infrastructure over 25 years with a discount rate of 6%, i.e. minimise the $ cost of supply	Objective
minimise the total present value of energy consumption, including embodied energy over 25 years, i.e. minimise the energy cost of supply	Objective
maximise the volumetric reliability of the non-potable component of the system supply	Objective
minimise total stormwater and wastewater discharge to the Gulf	Objective
time supply reliability of the potable component of the system demand must be 99.5%	Constraint
environmental flow releases from reservoirs must be met	Constraint
monthly target volumes of the storages in MLR catchments must be met	Constraint
the maximum amount of water extracted from the River Murray must be limited to 650 GL over any consecutive five year period	Constraint

The proof-of-concept implementation uses the Australian National Hydrologic Modelling Platform (NHMP), i.e. the Source platform developed within the eWater Cooperative Research Centre, and is the first study in Australia in which the NHMP has been applied to inform policy questions related to an IUWM plan being developed at a major city scale.

1.3 Critical decision points and caveats

Due to the many dependencies between tasks, internal communication was critical and task leaders met every fortnight to discuss progress, deal with emerging issues, and adjust timelines. A critical decision was made in December 2013 to proceed to optimisation with only five water sources (i.e. without groundwater, rainwater tanks and demand management). This decision was necessary to give the optimisation team time to conduct and complete their task. The incorporation of the seven sources and demand management into the simulation model continued.

Additionally all tasks were undertaken in parallel. Consequently, new data generated in tasks were not available to the modelling team at the time of building the models. This was overcome by using data from the literature and from past projects, and making appropriate assumptions. Therefore, the modelling results should be seen in light of this limitation and interpreted as being representative of a city such as Metropolitan Adelaide.

1.4 Structure of this report

Chapter 2 describes the key findings and outcomes from the various tasks undertaken within the project.

Chapter 3 describes the study area.

Chapters 4 – 11 report on collation and derivation of data that provide the necessary contextual information to inform optimising the sourcing of water for a city:

- Chapter 4 Community preferences and perceptions
- Chapter 5 Institutional and governance analysis
- Chapter 6 Connecting with stakeholders
- Chapter 7 Non-market valuation of the costs and benefits of urban water
- Chapter 8 Financial costs, energy consumption and greenhouse gas emissions for water supply options
- Chapter 9 Household use of water
- Chapter 10 Simulation and optimisation modelling, reports on the modelling of water mix scenarios and analysis of a subset of the solutions
- Chapter 11 contains some reflections on the optimisation results from community and governance perspectives.

The intent of this document is to report on the large and significant body of work that was undertaken in Project U2.2, conducted and funded through the Goyder Institute for Water Research, to support current and future urban planning requirements of the Government of South Australia. This body of work can be used to inform question such as:

- What are current preferences within the community for different sources of water, and what values and perceptions underlie those preferences? (Chapter 4)
- What are the institutional and governance issues that need to be considered when managing multiple sources of water? (Chapter 5)
- What lessons are there to be learnt from our experiences in engaging with stakeholders throughout the life of the project? (Chapter 6)
- How much do people value water - its role in urban green space, in improving the quality of water discharged to Gulf St Vincent, and in the services that it provides? (Chapter 7)
- How do we account for the costs of energy consumption and greenhouse gas emissions when considering the alternative water supply options? (Chapter 8)
- How do people use water within their homes – their patterns of use and choice of appliances? (Chapter 9)

- What data are needed to develop a planning model that can simulate supply, demand and discharge interactions resulting from utilising all sources of water, together with demand management (now and into the future – 2025 and 2050); and how can that model be used? (Chapter 10)
- What is a sensible approach to 'optimising' supply from the multiple water sources – what needs to be considered (now and into the future – 2025 and 2050)? (Chapter 10)
- How might different mixes of water sourcing be viewed by the community? (Chapter 11).

2 Key findings and outcomes

This chapter summarises the key findings from the chapters, and includes some commentary on the key outcomes of the project.

2.1 Community preferences and perceptions

The key findings from this body of work is that there is public support for using stormwater, wastewater and rainwater in order to protect water sources associated with natural ecosystems. They also need reassurance that authorities are properly managing the ecosystems, the water, and the expansion of the system.

2.2 Institutional analysis

This study found that institutional fragmentation, unclear ownership and access rights to 'new' water sources (stormwater, wastewater, managed aquifer recharge (MAR)), and funding for stormwater management are key governance/institutional challenges.

Institutional change needs to be through reform approaches that emphasise the development of coordinating mechanisms and improving intra- and inter-organisational relationships. Importantly, the State (of South Australia) already has a favourable policy environment to implementing IUWM strategy through its policy instruments (such as *Water for Good – A plan to ensure our water future to 2050* (2010)).

2.3 Connecting with stakeholders

Each task in the project had its research objectives and workplans, all of which required significant levels of engagement with agency staff and community groups. This needed to be coordinated and this was managed through having a person dedicated to this activity. This allowed for economic use of key stakeholders' time – nevertheless there was insufficient time (at the 'right' time) to build a true partnership with stakeholders to clarify and refine assumptions, source data, discuss and debate approaches.

The fact that water planning agencies engaged more strongly in the project than land use planners and local government suggests that work is required to demonstrate the relevance of these functions to water resources planning and integrated urban water management.

2.4 Non-market valuation of the costs and benefits of urban water

A key finding from this research is that the public values their coastal waters and are willing to pay for urban water projects that result in improvements in its quality. As an example, results of a survey suggests that a mix of projects that restores 25 days per year of water clarity and restores some reef and seagrass areas is deemed to be worth $AUD67.1M to Adelaide households.

The physical and wellbeing benefits of watering urban parks was studied, and this revealed a strong association between the level of physical activity and benefit attained, and different types of parks. People value and use their greenspace. In order to fully appreciate the health versus water trade-off, it may be worthwhile to investigate the importance of lush, green vegetation versus drought-tolerant vegetation to urban South Australians, and whether greater use of certain vegetation types by park managers impacts park use or benefit attainment.

The magnitude of potential ecosystem service impacts suggests that water supply investment decisions made without considering broad environmental impacts may well lead to socially suboptimal outcomes. Further, the study suggests, subject to uncertainties, that some environmental impacts such as downstream benefits of water for the River Murray, may not be as important as expected especially when compared with other impacts.

2.5 Financial costs, energy consumption and greenhouse gas emissions

The purpose of this body of work was to quantify the costs (money and energy) of the various water sources so that cost and energy could be incorporated into the optimisation. While many assumptions were made in the quantification, the purpose of this work was to derive appropriate data to inform the development of the framework, not to interpret or compare the costings.

2.6 Household use of water

Key questions that can now be answered as a result of this study include quantification of the impact of water efficient appliances, the impact of household age/composition/attitude on water use; and the children and high income effect.

Study households had an average water use of 245 litres/person/day, 14% higher than the SA Water average for metro Adelaide. Peak day usages was about 2.8 times the mean day, with 20% of households contributing 50% of the total demand on peak days.

The study revealed that people’s perceptions of their end use proportions are unreliable. However, there are distinct household water use types (related to income, age and attitude) with different use patterns and water saving practices.

The study also revealed that appliance efficiency was the primary contributor to reductions in indoor water use, not behaviour.

2.7 Simulation and optimisation modelling

An integrated urban water management (IUWM) simulation and optimisation model was constructed, bringing together many of the data collected in the other studies. The simulation model contained all seven water sources plus demand management, while the optimisation model contained five (without groundwater, demand management and rainwater tanks). Both models can be used to explore a large range of planning and operational questions.

From a results perspective, the modelling indicated that if minimising cost is the priority, then River Murray water is preferred for non-potable use; if reducing impact of poor water quality on Gulf St Vincent is the priority, then treated wastewater and harvested stormwater are preferred, with wastewater being more cost effective than stormwater; and rainwater tanks and in-house water efficient appliances can reduce demand.

2.8 Key outcomes

The programme has brought together a wealth of information, collated from the literature and local authorities, and from surveys within Adelaide, that provide context to the debate on how best to meet Adelaide's urban water needs. Key knowledge products include:

- patterns of residential water use in Metropolitan Adelaide, giving details of household water demand at the end use scale, the key drivers of household indoor water use, the impact of water efficient appliances on individual household end uses and the impact of household age, composition and attitude on water use
- willingness-to-pay for environmental improvements to the Gulf, and an improved understanding of the benefits of different types of green spaces in Metropolitan Adelaide
- an improved understanding of community preferences on supplementing metropolitan Adelaide's water supply in the future
- knowledge of costing of water supply and demand management options, energy and greenhouse gas assessment of water supply and demand management options
- a decision support framework for identifying cost-effective and reliable water sourcing options for Metropolitan Adelaide, for a given climate, relative to the objectives of cost, security of supply, energy and reductions in stormwater and wastewater discharges to Gulf St Vincent. A proof-of-concept of this framework was developed as a combined simulation/optimisation model, using a combination of data locally sourced (e.g. SA Water, DEWNR) and from the literature.

Underpinning the research addressing these issues, was a significant investment in the development of an integrated urban water management (IUWM) simulation and optimisation model to support 'what-if analysis' to understand the likely impact of different preferences for sourcing water (e.g. desalinated water over recycled wastewater).

These models are proof-of-concept only – there are not sufficient local data (i.e. data that describes metropolitan Adelaide) to parameterise the models such that the results can be interpreted in anything but broad terms. Nevertheless, they are sufficient to demonstrate the power of such models for exploring operational and policy questions. As is obvious from some of the questions posed above, many of the programme's activities were specifically designed to address these data gaps.

2.9 Products

The project was structured on tasks, and each task produced at least one significant model, technical report and/or journal article. These are listed by title in Table 2, with full citations details in References (Chapter12). The project structure, together with dependencies between tasks, is given in Appendix A .

In addition to the reports and journal articles, several datasets and models were developed or earlier versions enhanced. These are all listed in Table 2. This table does not include papers and presentations that were prepared and delivered at conferences and stakeholder workshops.

Table 2 List of products from the project and their accessibility

Product	Type	Access
A decision support framework for identifying optimal water supply portfolios: Metropolitan Adelaide Case Study: Volume 1 Main Report; Volume 2 Appendices (Maheepala et al)	Report	Goyder Institute for Water Research technical report series
Financial costs, energy consumption and greenhouse gas emissions for major supply water sources and demand management options for metropolitan Adelaide (Marchi et al)	Report	Goyder Institute for Water Research technical report series
Understanding and predicting household water use for Adelaide (Arbon et al)	Report	Goyder Institute for Water Research technical report series
Institutional arrangements for implementing diverse water supply portfolio in metropolitan Adelaide – scoping study (Keremane et al)	Report	Goyder Institute for Water Research technical report series
Urban water management in the 21st century – governance issues (McKay et al)	Book chapter	In Water management in the 21st century: Edward Elgar
The importance of irrigated urban green space: health and recreational benefits perspectives (Schebella et al)	Report	Goyder Institute for Water Research technical report series
Using the concept of common pool resources to understand community perceptions of diverse water sources in Adelaide, South Australia (Leonard et al)	Journal article	Submitted to Water Resources Research
Valuing coastal water quality (Hatton MacDonald et al)	Journal article	Submitted to Marine Policy
Taking time to think: time as a predicator of choice (Hatton MacDonald et al)	Journal article	Submitted to Journal of Choice Modelling
Reallocating state budgets: marine valuation exercise (Hatton MacDonald et al)	Journal article	To be submitted to Aust. J Resource Economics

Product	Type	Access
Ecosystem service impacts of urban water supply and demand management (Kandulu et al)	Journal article	To be submitted to Water Resources Research
Integrated Urban Water Management (IUWM) simulation model containing the seven water sources plus demand management, configured for metropolitan Adelaide. The model is a eWater Source schematic model – a key deliverable from the project – for 2013, 2025 and 2050	Model	Developed by CSIRO; contains confidential SA Water data and is not publicly available; CSIRO is the IP holder and the custodian is SA Water
A version of the IUWM simulation model that interacts with the eWater Insight optimisation module – for 2013, 2025 and 2050	Model	Developed by CSIRO and parameterised for optimisation by the University of Adelaide; contains confidential SA Water data and is not publicly available; CSIRO is the IP holder and the custodian is SA Water
Rainfall-runoff model for the metro Adelaide area. The model is an eWater Source catchment model – for 2013, 2025 and 2050	Model	Developed by EPA who are the IP holder and custodian. This model is available on request from EPA
Rainwater tank model, parameterised for metro Adelaide	Model	Used by CSIRO, using CSIRO proprietary model. CSIRO is the IP holder and the custodian. This model is available on request from CSIRO
Wastewater model, parameterised for metro Adelaide	Model	Developed by SA Water and CSIRO, and implemented by SA Water; contains confidential SA Water data and is not publicly available; SA Water is the iP holder and the custodian is SA Water
Enhancements to the Behavioural End-use Stochastic simulator (BESS) simulation model of household water use	Model	A proprietary model that was enhanced by the inclusion of data collected as part of the project. Queries to Dr Mark Thyer, Uni of Adelaide
Dataset of outflows time series from the Mt Lofty reservoirs (inflows to the catchment model)	Dataset	Developed by CSIRO and available through the CSIRO Data Access Portal. Metadata available through ANDS[1]. Used the CSIRO WAPABA model
Datasets of household use statistics	Dataset	Developed by the University of Adelaide and available by request to the University of Adelaide (Dr Mark Thyer). Metadata available through ANDS
Dataset of materials collected as part of social attitudes research conducted by CSIRO	Dataset	Not publicly available as private data. Metadata available through ANDS (custodian Dr R Leonard)
Dataset of material collected as part of the institutional risks study, conducted by Uni SA)	Dataset	Not publicly available as private data. Metadata available through ANDS (Dr J McKay)

[1] ANDS – Australian National Data Service (http://ands.org.au). Making datasets available through ANDS takes time. It is anticipated that these datasets will be visible through ANDS sometime in late 2014 or early 2015.

3 The study area

This chapter describes the study area, mainly in terms of its characterisation for the purposes of water supply and demand simulation modelling. Much of the content is adapted from the companion report by Maheepala et al. (2014) and the reader is referred to that report for more details.

3.1 Geographic extent

The area covered by Metropolitan Adelaide extends from the north of the town of Gawler in the north to Sellicks beach in the City of Onkaparinga in the south, and from east of the towns of Bridgewater and One Tree Hill in the east, to the coast of the Gulf St. Vincent. The study area includes a majority of the area covered by Metropolitan Adelaide and the major growth areas located outside the Gawler local government area, i.e. Concordia and Roseworthy growth areas, and excludes a portion area governed by Adelaide Hills Local Government, between Kangaroo Creek and Mount Bold reservoirs (Figure 2). In this report, the study area is referred to as 'Metro(politan) Adelaide'.

The areas covered by the social preference and institutional risk studies, and the household water use study, are contained within this boundary.

3.2 Climate

Metro Adelaide has mild winters with moderate rainfall and hot, dry summers. The mean maximum summer (December-February) temperature is 29˚C, with some days going over 40˚C. Mean minimum winter (June-August) temperature is 15˚C. Mean annual rainfall is 544 mm, with monthly rainfall varying from 15 mm in February to 79 mm in June.

Expected changes in annual rainfall and average annual temperature in year 2025 are a 19.9% reduction and a 0.52˚C increase, respectively (Table 3). In the year 2050, the expected changes rainfall and the average annual temperature were a 38% reduction and a 1.06˚C increase, respectively (Table 3). These estimates were derived using moderate rainfall and temperature scenarios in CSIRO's OzClim Climate Scenario Generator.

Table 3 Metropolitan Adelaide annual rainfall and temperature in 2025 and 2050 (source: CSIRO OzClim Climate Scenario Generator)

Year	2025	2050
Reduction in rainfall compared to 1990	19.9%	38%
Reduction in rainfall compared to 2013 (computed by using linear interpolation)	6.82%	23.43%
Change in temperature compared to 1990 (^{0}C)	0.52	1.06
Change in temperature compared to 1990 (^{0}C) (computed by using linear interpolation)	0.18	0.65

Figure 2 Geographic extent of the study area of metro Adelaide, being the red boundary

3.3 Water sources and demand

Current

The public water supply side of the urban water cycle in Metropolitan Adelaide draws on a diverse network of sources including surface water from ten reservoirs spread throughout the Mount Lofty Ranges with supplementary water from the River Murray, and more recently (since late 2011) desalinated seawater from the Adelaide Desalination Plant. On average, metro Adelaide annually utilises about 26% of its reclaimed wastewater and about 5 GL (25%) of its harvested stormwater for non-potable uses such as open space irrigation and peri-urban irrigation. Adelaide also has 44% of households with rainwater tanks (the second highest in Australia after Brisbane) used for a variety of purposes from garden use to indoor uses such as toilet flushing, clothes washing and hot water.

Over the period 2004/05 to 2010/11, SA Water supplied on average 139 GL/year of water to metro Adelaide. On average 60% of this water came from the Mount Lofty Ranges and the rest from the River Murray. However, the supply from the River Murray can reach up to 90% in dry years.

Metro Adelaide has 26 operational stormwater harvesting schemes located in eight catchments (Smiths Creek, Adams Creek, Greater Edinburgh, Brownhill/Keswick Creek, Dry Creek, Christie Creek, Field River, Port Road), providing water to open space irrigation, golf courses and sporting grounds. Their combined potential yield is about 20 GL/year, though only about 5 GL/year is currently utilised.

The area is serviced by three major wastewater treatment plants (WWTPs) at Bolivar, Glenelg and Christies Beach. Bolivar WWTP processes almost 70% of metro Adelaide's wastewater. All three plants produce recycled water and distribute it for non-potable demand of non-residential use. Table 4 lists their current plant and recycling capacities.

Table 4 Existing capacity to produce recycled water at Bolivar, Glenelg and Christies Beach WWTPs

WWTP	Current plant capacity (ML/year)	Current recycling capacity (ML/year)
Bolivar	60,225	38,325
Glenelg	21,900	3,800
Christies beach	16,425	16,425

Future

The *Water for Good* plan (2010, Figure 22) estimated a water deficit for Greater Adelaide by 2050 equal to 32 GL/year and 68 GL/year under moderate and extreme dry year events. These estimates considered increased demand due to the increased population, reduced water yield due to climate change, provision of 100 GL/year from the desalination plant and 50 GL/year water demand savings from Water Proofing Adelaide (Government of South Australia, 2004). Should additional water measures be implemented (additional 40 GL/year from alternative supplies between 2025 and 2050 and demand savings of 50 GL/year), the plan estimated a water surplus by 2050 equal to 58 GL/year and 22 GL/year under moderate and extreme dry year events.

It has been suggested that in 2020 about 220 GL/year would be required to satisfy the demand of metro Adelaide (Marsden Jacob Associates, 2006; ATSE, 2012). Demand modelling conducted by the project team (reported in Maheepala et al. (2014)) predicted demand of 210–213 GL/year by 2050 (Table 5), noting that these figures reflect estimated reduction in future demand due to installation of efficient toilets, 3-star showerheads and front loading washing machines).[2]

Table 5 Average water demand of the study area in 2013, 2025 and 2050 (computed by using SA Water's CDD12 monthly demand model)

year	Average over 50 years (July 1963 – June 2013) ML/y	Average over 30 years (July 1983 – June 2013) ML/y
2013	170,456	172,518
2025	180,944	183,108
2050	210,413	212,880

3.4 Population

For the purposes of this study, the population of the Greater Adelaide Region was taken as the population of the study area. Population statistics for 2011, and projected to 2013, 2025 and 2050 are summarised in Table 6. The assumptions behind the derivation of these numbers are detailed in Maheepala et al (2014).

Table 6 Population statistics for metro Adelaide now and into the future

Year	2011	2013	2025	2050
Population (million)	1.225	1.23	1.35	1.56
Average household size (people/household)	2.4	2.39	2.21	1.88
Number of households	510,417	514,644	610,860	829,787

The study of preferences of different groups of people drew from community and other groups located within the study area.

[2] For more details on the demand modelling method and assumptions, you are referred to Maheepala et al (2014), Section 3.6

4 Community preferences and perceptions

This chapter discusses the methods and the findings of the social analysis study. The team was Rosemary Leonard (task leader), Andrea Walton, Carol Farbotko, Aditi Mankad, Melissa Green, Anneliese Spinks and Sarah Malkin (CSIRO).

4.1 Purpose

When looking at supplying potable and non-potable water from multiple sources, community preferences and perceptions are important in guiding strategic decisions about where best to focus investment, and education. This component of the project aimed to elicit community perceptions of the merits and drawbacks associated with the use of each water source, and people's rationales for preferring one source over another.

4.2 Methods

Nineteen (19) focus group meetings were held over the life of the project, involving 130 people, designed to elicit community perceptions of the merits and drawbacks associated with the use of each water source, compared to the use of all water sources. Each meeting resulted in participants voting for (i.e. ranking) each water source. To get some sense of how these results might translate to the people of Adelaide more generally, data for three attitude scales was collected in this study and compared to an earlier Adelaide-wide survey (Mankad et al. 2013).

4.3 Key findings

Three key ways of categorising water supply planning emerged from these discussions and are presented in Table 7. Management of water embedded in ecological systems is perceived to be distinct from management of water embedded in human technological systems. This distinction depended on perceptions of geographic boundedness of the ecological system and whether or not the source was perceived as finite. A third category was expanding overall supply. Three overarching concerns were common to all three categories; authority to govern, wastage of resources, and community engagement.

Table 7 Categories of water supply planning reflected by Adelaide water users

	Management of the ecological systems	Management of the water	Expanding the supply
Water sources	River Murray Mt Lofty catchments Aquifers Gulf water around the Desalination plant	Stormwater Rainwater tanks Recycled wastewater	Stormwater Rainwater tanks Recycled wastewater
Rules	Don't over use the ecological system Don't damage the ecological system	Keep water high quality and safe	Ensure a diversity of water sources
Key attitudes	Citizens see these systems as: • Bounded geographical ecological systems • a depletable source (including a healthy gulf)	Citizens see these sources as: • under-utilised • wasted opportunities • not needing to be restricted • not geographically bounded	Value proposition: • Delivers value: water security into the future; fit-for-purpose system (eg third pipe); create a legacy • Cost considerations: makes the most of existing assets and investments
Overarching issues	• Authority to govern – managing the system, the water and expansion of the system • Prevent wastage of resources – water, financial, existing infrastructure, and energy • Community engagement – education, information, consultation, interaction		

There were two distinct positions on how distribution systems could be expanded into the future. Some supported adding water from the alternative sources to the existing distribution system because they viewed this as a cheaper alternative to the installation of third-pipe systems. Others supported the idea of fit-for-purpose water, and that two distribution systems should be in place in the future; one for potable and one for non-potable supply, because, in the long run a fit-for-purpose system would involve reduced wastage of money and resources. Views about distribution influenced the three distinct positions on the importance of cost in making final decisions about water supply. One position was that options should be considered irrespective of cost, as long as they delivered safe and reliable drinking water for the future. The second position was that cost concerns should be overridden when the investment delivered a valued outcome, such as a third-pipe system, which they viewed as a benefit to future generations. The third position was that cost was the most important factor and the cheapest, economical [option] that works efficiently was sufficient.

There were no differences between this study and that reported in Mankad et al (2013) on attitudes to not wasting water and the value of water. The focus group attendees were significantly higher on pro-environmental behaviours but the effect size was small (Leonard et al. 2014 submitted). Table 8 lists order of preferences for the different water source options from the two studies, noting that these results are not directly comparable to those in Mankad et al (2013) as they were collected for different purposes, with very different sample sizes. The term *Water Thrift* in Table 8 reflects the degree to which people voted for capturing water, reusing water and reducing consumption, and was higher where respondents had been exposed to WSUD (water saving urban design) initiatives.

Table 8 Ranks and loadings for the different water sources collected from this study and from the Mankad et al (2013) study

Water sources	Water Thrift scale Ranks & factor loadings N=130	Ranks & ratings of importance on a 1-5 scale (Mankad et al 2013) N=1031
Demand management - water efficiency	0.60	Not collected
Stormwater	1 0.59	4 3.94 (0.92)
Recycled wastewater	2 0.49	5 3.80 (1.00)
Rainwater/roof water	3 0.43	1 4.34(0.88)
Groundwater	4 0.01	6 3.55 (1.01)
Desalinated seawater	5 -0.42	7 3.42 (1.10)
Mt Lofty Ranges catchment	6 -0.60	2 4.22 (0.88)
River Murray	7 -0.70	3 4.07 (1.01)

4.4 Summary

Our conclusion is that the people of Adelaide are concerned about water and there is public support for recognising and protecting water sources associated with natural eco-systems by greater utilisation of alternative sources such as stormwater, wastewater and rainwater. Even amongst groups at the lower end of the *Water Thrift* scale there was some support for that strategy and we know from the Adelaide-wide survey that for stormwater at least there is more support than resistance (Mankad et al 2013). This qualitative study suggests that, whatever strategy is used to provide a secure and safe water supply, there will need to be some key considerations. The public need reassurance that authorities are properly managing the ecosystems, the water, and expansion of the system. Such reassurance is built through transparency and responsiveness. Prevention of waste of water, money, existing infrastructure, and energy will be important strategies.

5 Institutional and governance analysis

This chapter discusses the methods and the findings of the legal and governance scoping study that was conducted to identify governance challenges and potential options to support the implementation of an integrated urban water management strategy in Metropolitan Adelaide. The team was Jennifer McKay (task leader), Ganesh Keremane and Zhifang Wu of the University of South Australia.

5.1 Background

Implementation of a portfolio of water sources that are fit for diverse uses is an institutional challenge. This means traditional approaches that have relied heavily on large scale infrastructure development (dams, levees, and conveyance facilities) have to operate within a new integrated approach that emphasises integration of all components of the urban water cycle and has a portfolio of water supply sources. However, effective implementation of the integrated approach depends on solutions beyond technological, and now depends on social and institutional aspects of water management. In line with this diagnosis this study focussed on identifying the governance challenges in implementing an integrated urban water management strategy in Metropolitan Adelaide.

5.2 Methods

The study included review of international and Australian case studies of implementing a portfolio approach, particularly the institutional arrangements for diversifying the water supply sources. The international case studies included experiences from Singapore, Israel, Windhoek (Namibia), and California (USA). In Australia, the study reviewed the experience of implementing an integrated urban water management strategy in the major cities. In addition, the study conducted several face-to-face discussions with key actors representing different stakeholders/agencies (example SA Water, DEWNR, Local Councils, NRM Board) who are involved in delivering safe and secure water and wastewater services to Metropolitan Adelaide.

5.3 Key findings –initial interpretations

Overall, the review of international and Australian case studies indicate there is a growing support for implementing a portfolio of water supply sources to meet the needs of growing population and rapid urbanisation. The governments at all levels and the urban water industry have undertaken a range of investments and actions to support integrated urban water management objectives. However, it was observed that the institutional arrangements for delivering these objectives are not always clear. The literature points out that the impediments to implementing an integrated urban water management (IUWM) strategy are not generally technological, but are, instead, socio-institutional. It further suggests while the progress on the scientific and technical aspects related to IUWM has been commendable, there are significant institutional aspects that need equal attention. A wide range of social and institutional barriers to IUWM adoption including insufficient practitioner skills and knowledge, organizational resistance, lack of political will, limited regulatory incentives and unskilled institutional capacity were identified.

5.3.1 International case studies

International case studies reviewed in this study included Singapore, Israel, USA, and Windhoek. It was clear from the review that there is no 'one size fits all' solution to diversification of water supply; it has to be tailored to suit the specific characteristics and requirements of the different cities/jurisdictions. However, there are some lessons to learn from the international experiences, particularly Singapore and Israel who have implemented the IUWM strategy effectively. Even though these jurisdictions are unique in some aspects, they have a lot to offer for implementing IUWM particularly in areas of cross-sector and cross-agency coordination, integration of land use planning and water management, and carefully planning and implementing water programs through partnerships and public education. Table 9 highlights the water sources and the institutional arrangements in the selected international cases.

Table 9 Summary of international case studies

Country/ jurisdiction	Water sources supply side	Water sources demand side	Governance/institutional setting
Singapore	Four National Taps comprising water from local catchments, imported water, NEWater, and desalinated water	Public Utilities Board (PUB) uses water pricing, mandatory requirements (e.g. installing water saving devices) and public education to manage water demand	• Single national agency- PUB- manages the whole "water loop" in an integrated and holistic manner • PUB has a high degree of autonomy and strong government support to carry out its role as the national water agency. • Close and efficient interagency cooperation
Israel	River waters, springs, floodwater run-offs, ground water, recycled purified sewage and irrigation waters, and desalination	• Water conservation and demand management programs including a combination of technology diffusion (upgrading inefficient plumbing infrastructure, car wash and toilet regulations) and seasonal usage restrictions (e.g. spray irrigation in the urban sector, and drip and sub-surface drip irrigation in the agricultural sector. • Another pioneering policy decision as part of demand management strategy was the 'Virtual Water' Policy whereby the authorities decided to import a majority of its grain needs instead of growing them in Israel.	Single Professional Board - Israeli Water Authority- is responsible for managing the whole "Water Chain".

Country/ jurisdiction	Water sources supply side	Water sources demand side	Governance/institutional setting
Windhoek (Namibia)	Groundwater, surface water, and reclaimed water	Market mechanisms (pricing), and direct interventions (introducing special measures including policy measures, information programs, regulations, and technical measures through municipal bylaws for water saving.	One government department- Department of Infrastructure, Water and Technical Services through its six divisions manage the supply, distribution and quality of potable water as well as the collection, reticulation and treatment of sewerage water.
California (USA)	Groundwater, imported surface water, ASR/water Banking, recycled water (stormwater, wastewater), and desalination	Water Demand Management Measures i.e., measures, practices, or incentives implemented by water utilities to permanently reduce the level or change the pattern of demand.	• California has a decentralized governance system and urban water management authority is allocated to nearly 300 local water departments, special district governments, and private water suppliers within the state. • New integrated water management approaches are emerging in the USA and the state government of California passed the California Integrated Regional Water Management Planning Act (IRWM Act) to encourage local water agencies to cooperatively manage their water supplies for regional benefit and encourage coordination among agencies to improve regional water management.

Source: Literature review

5.3.2 Australian case studies

Review of Australian experiences with diversifying water supply sources indicated that most States have embarked on implementing the IUWM approach to supply and secure water for urban areas. Overall the strategy has been to develop efficient and flexible urban water systems by adopting a holistic approach in which all components of the urban water cycle are integrated, and includes a mix of water supply sources – freshwater(surface water, groundwater), and produced water (desalinated water, stormwater and treated effluent). However, implementation is a challenge given that there are different institutional models for urban water management across Australia. Water management in the Australian States and Territories is the responsibility of various government agencies, water authorities and water utilities. Furthermore, the inclusion of 'new sources' into the water supply mix has resulted in a complex entitlements regime and related issues about security to access because the current entitlement arrangements governing different sources of water within the urban water supply are not clearly defined. Consequently some of the issues for Australia include:

- the variety of regulatory regimes that have been involved and lack of overall coordination
- lack of clarity about roles, responsibilities and accountabilities within the urban water sector
- extreme levels of restructuring and institutional role separation within the public sector departments

- differences in power or conflicts of interest among water agencies related to addressing water rights issues, pricing, and dealing with opponents to water reuse.

In relation to diversifying water supply sources in Metropolitan Adelaide, there are seven sources and demand management ((Appendix B). In this regard, Adelaide is unique in the depth of its approach to optimising several sources of water. While there are different agencies/organisations involved in various aspects of water management in South Australia, the State leads the country in stormwater capture and reuse, rainwater tank ownership and wastewater recycling. The State also has a favourable policy environment to implement IUWM strategy in the form of the following policy instruments:

- Water for Good A plan to ensure our water future to 2050 (2010)
- The 30-Year Plan for Greater Adelaide (2010)
- Stormwater Strategy – the future of stormwater management (2011)
- Water Sensitive Urban Design -creating more liveable and water sensitive cities in South Australia (2013).

Nevertheless, opportunity to improve exists, mostly in the policy and legal areas as indicated during the interviews with key policy actors in Adelaide. Most of the policy and legal challenges highlighted by the interviewees were related to the 'new' water sources such as stormwater/wastewater and in agreement with those identified in the literature review. The challenges for Adelaide at large include:

- institutional fragmentation
- unclear access rights to the 'new' water sources (e.g. stormwater, wastewater)
- funding for stormwater projects due to lack of a clear and agreed approach to manage the resources in question
- public perceptions and acceptance of 'new' water sources.

5.4 Summary

In summary, there is no 'one size fits all' structural arrangement for implementing a diverse portfolio of water supply sources in Australia and/or Adelaide. It has to be tailored to suit the specific characteristics and requirements of the different cities/jurisdictions. Addressing the institutional challenges to implement IUWM requires engaging the governments, corporations and society in a three way collaborative effort. The focus therefore has to be on implementing institutional change through reform approaches that emphasise the development of coordinating mechanisms and improving intra- and inter-organizational relationships. This means creating favourable institutional contexts, with the appropriate mix of public and private actors who are supported by coherent legislative and policy frameworks. Also there is a need for further exploration of the coordination issues and providing a model(s) to enable the transition.

6 Connecting with stakeholders

This chapter discusses the strategies and activities put in place by the project to provide formal access to key government agency staff and their knowledge of the urban water system. The team was Kathryn Bellette (lead), Flinders University, supported by all task leaders.

6.1 Purpose

Recognising the importance of having an effective communication pathway between the research team and key stakeholders, the project included a task devoted to stakeholder engagement. This task managed the overarching stakeholder engagement activities, while each task managed its own technical engagement programmes.

6.2 Key learnings and observations

- Synchronising timing between key project decision points and enthusiasm of the stakeholder groups was difficult to achieve. Engagement was strongest at the start of the project, when we were developing methods, and weakest towards the end when we needed strong engagement. And, regardless of the number of presentations throughout the project, expectations of outcomes, especially in terms of accuracy of results, were higher than could be achieved within the timeframe, and with the data to hand.
- Water planning agencies engaged more strongly in the project than land use planners and local government – suggesting that work is required to demonstrate the relevance of land use planning and local government to water resources planning and in enabling the recommendations arising from urban water project outcomes
- Several of the stakeholders were engaged in more than one Goyder Institute for Water Research project – the establishment of one reference panel for all Theme projects may assist in integration across theme projects and also provide a framework for the economical use of key stakeholders' time

6.3 Method

A Project Reference Panel and a wider stakeholder group were formed and endured throughout the life of the project. Formal engagement was through a structured set of meetings with the Reference Panel, wider stakeholder workshops (water resources/state government and local government sectors) and an open information session directed to an even wider group of invitees (water resources sector/development and other sectors/NGOs/broader government portfolios).

6.3.1 Project Reference Panel

The composition of the Reference Panel was selected from key agencies in terms of technical expertise or policy interest. Its role was to provide:

- a formal mechanism for collective communication between the project team and key government policy makers with direct responsibilities relating to metropolitan water resources management and provision of services
- a conduit for each organisation to participate in discussions at key points in the project implementation and subsequent planning
- advice on how to maximise relevance and application of research outcomes to policy

The membership of the Project Reference Panel is listed in Appendix A . The panel met on seven occasions throughout the duration of the project, in addition to being invited to participate in the stakeholder workshops.

6.3.2 Stakeholder workshops

The purpose of the stakeholder workshops was to test the approach and direction the team was taking the project, specifically to:

- define the project vision, objectives and measures
- provide feedback on preliminary outputs of hydrological, carbon footprint, social, economic and institutional analyses, and elicit values and preferences for measures, and on how to best finalise outputs of the project.

The workshops ran well, and delivered what was required by the research team. A good variety of organisations attended and the breadth and depth of discussion was suitable and constructive.

6.3.3 Information session

An information session was run in conjunction with DEWNR on the SA "Blueprint' for urban water for a wide group of representatives from NGO's, industry and government in June 2013.

The outcomes achieved through the above series of gatherings met the requirements of the task, both in terms of process and provision of meaningful feedback that assisted in guiding the task leaders and their teams on how to progress their tasks to provide the most meaningful results practicable for the stakeholders, delivered in a stakeholder friendly format. Reference panel members attended panel meetings to varying degrees, with the highest level of engagement from DEWNR, EPA and SA Water. This was put down to competing priorities.

The engagement of the EPA and SA Water representatives was the most effective. Officers from these organisations were actively involved in specific tasks, which provided the momentum for these officers to be active and first hand informed members of the reference panel.

6.4 Summary

This activity was only one of the communication vehicles adopted by the project team. It was complemented by presentations at conferences and workshop which were conducted at task level. The Project Reference Panel provided a valuable forum for reviewing material in the early stages of its development – this was crucial for fine-tuning survey material and in how to interpret, and present results. The stakeholder workshops were well attended and provided a valuable forum for the project team to present their research – timing being towards the end of the working day – it would be valuable to get feedback from participants as to the benefit of these workshops, from their perspective.

It proved useful having a local person, with strong local networks within government agencies, dedicated to this task – this took some of the load off the task leaders and provided a clear communication pathway with stakeholders.

7 Non-market valuation of the costs and benefits of urban water

This chapter discusses the methods and the findings of the costs and benefits of different urban water options to support the implementation of an integrated urban water management strategy in Metropolitan Adelaide. The team was Darla Hatton MacDonald (team leader, CSIRO), John Kandulu (CSIRO), Sean Connell and Bayden Russell (University of Adelaide) and Morgan Schebella (University of South Australia).

7.1 Purpose

The objective of this task was to identify the costs and benefits of different urban water options, where feasible in quantitative terms. Three studies were identified and undertaken:

- estimate the community values associated with marine species abundance in Gulf St Vincent for recreation and biodiversity conservation
- explore the utility of an ecosystem services approach to quantify impacts in terms of the net benefits and costs associated with the different water supply options on third parties, including the environment
- assess the health and recreation benefits associated with green spaces as it was identified by stakeholders, such as SA Water, that these could dwarf many of the other potential externalities associated with water

7.2 Methods and key findings

7.2.1 Valuing coastal water quality

This study was conducted as a choice experiment to elicit the preferences of people living in Adelaide for a set of coastal (Gulf St Vincent) water quality improvements, with results presented in terms of the (non-market) values associated with clarity, seagrass habitat and the health of rocky outcrop reefs. Data collection was via a survey which described a series of feasible options for managing stormwater and wastewater, as well as the benefits of different management actions. Each feasible option (a scenario) favoured one attribute (e.g. improvement in water clarity), over another. Two costing instruments were considered - a levy on all Adelaide households; and a change in government budget priority. Table 10 summarises the ranges used for each attribute:

Table 10 Summary of attributes and the ranges used in creating feasible options

Attribute	Levels in current situation	Levels in no-status-quo options
Water clarity	50 days of murky water	50, 30, 20, 10, 5, 0 days
Seagrass	60% of seagrass remaining	60%, 65%, 70%, 85%, 80%
Healthy reef areas	3 of 19 reefs in good condition	3, 5, 7, 9, 11, 13, 15
Levy amount per year for years	No increase in levies	$25, $25, $75, $100, $125, $150

The survey was refined over a period of 9 months through the use of focus groups and input of a government agency working group that provided background reports and advice; and conducted over a five-week period in late 2013/early 2014. The response rate was 18.9%, with a slight over-representation of women, older individuals and people with degrees.

Based on the survey results, and assuming they are representative of the Adelaide region as a whole, Adelaide households would be willing to pay in the order of AUD $12.4m to reduce the turbidity (i.e. improve the clarity) of coastal water from 50 to 25 days; $18.9M to achieve a 10% increase in seagrass; and $35.8M to restore five additional reefs to good health.

This study is reported in detail in Hatton MacDonald et al. (2014).

7.2.2 Ecosystem service impacts of urban water supply and demand management

This study was conducted as a desk exercise, using information extracted from existing literature. Ecosystem services are the benefits, broadly categorised as provisioning, cultural, regulating and habitat, provided by nature that contribute to the well-being of people. Twelve potential ecosystem service impacts associated with the different urban water management options were identified and organised into these four categories (Table 11).

Table 11 Twelve ecosystem service impacts associated with the urban water supply options, together with a summary of their costs (negative) and benefits (positive)

Water source	Ecosystem service impact	Estimate AUD $/kL
Mt Lofty Ranges catchments	Provisioning – food and fibre	-0.06 to -0.15
	Cultural amenity	-0.03
	Salinity regulation	-0.55 to -1.27
River Murray	Provisioning – food and fibre	-0.08 to -0.15
	Habitat services	-0.03
	Recreational amenity	-0.06
	Salinity regulation	-073 to -1.21
Wastewater reuse	Provisioning – food and fibre	0.13 to 0.15
	Nitrogen regulation	0.07
	Salinity regulation	-2.16 to -2.30
Desalinated water	Salinity regulation	-0.62

Water source	Ecosystem service impact	Estimate AUD $/kL
Stormwater harvesting	Coastal amenity	1.03
	Salinity regulation	0.03 to 0.19
	Estuarine habitat support	0.00 to 0.05
	Climate regulation	0.02 to 0.07
	Cultural amenity	0.02
Conservation (demand management)	Freshwater provision	-0.59 to -1.87

Overall the study found that salinity and salinity regulation costs of sourcing mains water for domestic uses are high, estimated at up to $2.30/kL from reuse of wastewater, up to $1.27/kL for water sourced from the Mt Lofty Ranges catchments, up to $1.21/kL for water sourced from the River Murray and $0.62/kL for desalinated water.

Coastal amenity benefits from reduced pollution to coastal waters through storm and wastewater management are significant, estimated at up to $1.03/kL.

This study is reported in detail in Kandulu et al. (in review).

7.2.3 Irrigated urban green space: health and recreational benefits perspectives

This report, the outcome of a studentship, reviewed international literature on green space relevant to human health and well-being. This was complemented by a pilot empirical study at local government scale (the City of Campbelltown) that examined the influence of park irrigation on park-based physical activity and benefit attainment.

The study revealed an association between the level of physical activity and benefit attained through use of different types of urban parks. For example, linear parks (e.g. the Torrens River Linear Park) were found to facilitate significantly more physical activity than traditional community parks; while the latter facilitated more non-physical benefits such as mental health. The literature and empirical results suggest that there may be merit in linking green spaces with vegetated green corridors, connected through trail networks using natural corridors, such as waterways, creeks and roadsides.

This study is reported in detail in Schebella et al. (2014).

7.3 Summary

This task explored a range of approaches to value the services that urban water provides, ranging from its role in providing greenspace, to its impact on the receiving waters of Gulf St Vincent. All three studies were designed to fit within the resource and time constraints of the project, and were thus limited in their size and representativeness. Nevertheless, all three studies have provided valuable insights into the relationships between urban water, people and the environment. In all cases, the results can inform public policy discussion including the benefit-cost analysis of investment in urban infrastructure.

- This research suggests that the public values the quality of their coastal waters and are willing to pay for urban water projects that result in improvements in its quality. Assuming survey findings are representative of the broader Adelaide community, a mix of projects that restores 25 days per year of water clarity, seagrass area from 60% to 70% of the original area and five reef areas is worth $AUS67.1M to households in the Adelaide metropolitan area.
- The use of choice modelling to elicit and quantify the non-market benefits of investing in urban water improvement complement cost-benefit analyses when determining priorities for urban water investment.
- The study has demonstrated the utility of considering ecosystem services when evaluating the impacts of different water sources. It highlighted the impact of increased salinity in wastewater reuse, and the time cost associated with conservation in the form of water restrictions on outdoor water uses.

8 Financial costs, energy consumption and greenhouse gas emissions for water supply options

This chapter describes the collation of cost, energy and greenhouse gas emissions input data for use in the optimisation study. The team was Angela Marchi, Graeme Dandy and Holger Maier (The University of Adelaide).

8.1 Purpose

Differentiating between the many possible mixes for sourcing urban water requires characterising those water sources such that they can be compared and assessed against a set of objectives, whether they be of a financial, social, or environmental nature. Two aspects of the environmental impacts of the supply sources are the energy used to supply the water, and the gross greenhouse gas emissions during the process. These data were required as input to the multi-objective algorithm used in the optimisation modelling (described in Chapter 10).

8.2 Method

This was a desktop exercise, with data acquired from the literature or provided by agencies. The potential supply option were disaggregated to reflect a wide range of implementations (Table 12).

Table 12 Sub-categories of the water supply options for which costings were derived

Water source option	Sub-categories
Mount Lofty Ranges catchments	• Water in an average year • Water in a dry year
River Murray	• Pumping – current entitlement • With additional pipe capacity
Desalinated water	• Includes pump replacement
Groundwater	• Includes pump replacement
Stormwater – wetland without ASR	• Harvesting • Distribution • Irrigation of public open space • Greenfield 3rd pipe system for non-potable use • Brownfield 3rd pipe system for non-potable use • Blending with treated wastewater then greenfield 3rd pipe system for non-potable use • Blending with treated wastewater then brownfield 3rd pipe system for non-potable use • Transfer to reservoir for potable use
Stormwater – wetland with ASR	• Harvesting • Distribution • Irrigation of public open space • Disinfection and irrigation of public open space • Blending with treated wastewater and irrigation • Greenfield 3rd pipe system for non-potable use • Brownfield 3rd pipe system for non-potable use • Blending with treated wastewater then greenfield 3rd pipe system for non-potable use • Blending with treated wastewater then brownfield 3rd pipe system for non-potable use • Direct injection for potable use • Transfer to reservoir for potable use • Treatment and transfer to reservoir for potable use
Recycled wastewater	• Includes three WWTPs
Roof / rainwater	• 2 kL rainwater tanks for indoor and outdoor use • 2 kL rainwater tanks for outdoor use only • 5 kL rainwater tanks for indoor and outdoor use • 5 kL rainwater tanks for outdoor use only
Demand management – water restrictions	• 10% of current total demand • 20% of current total demand • Advertisement costs
Appliances	• Washing machines • Tap timers • Low flow showerheads • Low flow taps • Dual flush toilet

Estimates of the costs of the different water supply options were derived as capital and operational costs, noting that capital costs were considered as sunk costs. Energy and gross greenhouse gas (GHG) emissions were estimated as capital[3] and operational energy and GHGs, respectively.

A range of methods were used to compute these costs and these are fully described in Marchi et al. (2014).

The baseline for costs in this study was March 2013. Where possible, local data (from metro Adelaide or from South Australia) were used; where these were not available, values from the literature were used. A measure of uncertainty was ascribed to each value, reflecting the reliability of the values.

Costs for a subset of water sources are given in

[3] Capital energy is referred to as 'embodied energy' and estimates the energy used to build the intervention (i.e. how much energy is used to produce the concrete to build the housing of the pumping station). Embodied and operational energy can then be converted into embodied and operational GHGs by using an emission factor.

Table 13. This table includes a qualitative classification of the reliability of the values: high (*H*) – values sourced from direct observation or estimated through the use of a calibrated model of the actual system are classified as having high reliability; medium (*M*) – values based on observations or estimates made for closely related systems or developed from multiple literature sources; low (*L*) – values derived from literature values that have been developed from a single or few literature sources are classified as having low reliability.

Table 13 Volume of water supplied/saved, capital and operational costs for some categories of water sources, together with a qualitative classification of the reliability of the values (Source: adapted from Table 1, Marchi et al (2014))

Water source	Volume GL/y	Capital cost $'000/ML/y	Operational cost $/kL
Mt Lofty Ranges catchments	121(average year)[H] 30 (dry year)[H]	$0	$0.24[H]
River Murray	320 in total (130 (current entitlement)[H] + 190 (additional pipe capacity)[M]	$13.96m every 20 years for pump replacement[L]	$0.44 for current entitlement[H] $0.74 in excess of current entitlement[M]
Desalinated water	100[H]	$1.7m every 20 years for pump replacement[L]	$1.00 + $30m/y[H]
Groundwater	3[L]	$1.0[L] + $0.12m every 20 years for pump replacement[L]	$0.36[L]
Stormwater – wetland without ASR – irrigation of public open space		$18.9[L]	$0.45[L]
Stormwater – wetland with ASR – irrigation of public open space		$8.0[L]	$0.42[L]
Recycled wastewater	98.55[H]	$20.3[L]	$2.00[L]
2 kL rainwater tanks (design life 25 years)	2.9 for indoor & outdoor use[L]	$139.4-$164.7[L]	$0.36[L]
Demand management – water restriction	10% of current total demand[L]	$71/year/household[L]	-
Demand management – low flow taps	0.4[L] (water saving 3.34 kL/year/household – 2 appliances per house are installed)[L]	$752 for 2 appliances[M] (10 year design life)	-

For desalinated water (the Adelaide Desalination Plant), the operational cost is a fixed $30million/year, regardless of the amount of water produced, and $1/kL to account for energy, chemical and membrane consumption.

Capital cost of building wetland and stormwater harvesting schemes used Wallbridge and Gilbert (2009) to estimate costs of wells and wetland/biofiltration constructions. Costs for pumping stations, treatment plants and distribution system were based on the Parafield stormwater harvesting scheme.

The volume for wastewater was calculated as current plant capacity of 58.55 GL/year being increased to 98.55 GL/year if Bolivar and Glenelg plants were to be upgraded. Costs were based on the Glenelg scheme as it was thought to be more representative of future wastewater reuse schemes.

The use of rainwater tanks could save 1.3 GL/year if used only for garden watering, or 2.9 GL/year if used for outdoor use and toilet and laundry use. The cost estimate for a 2 kL tank in

Table 13 was based on it being connected to 100 m^2 of roof area.

8.3 Summary

This was a large data acquisition and analysis study to provide estimates of attributes of the various water sources for the simulation and optimisation modelling. There are many caveats on the figures presented in the report, due to the uncertainty in the data and the number of assumptions that needed to be made to derive the figures. An estimate of the reliability of the data is assigned to each figure. Costs and energies for the Mount Lofty Ranges, River Murray and desalinated water are considered to be most reliable as there is more information available and the references are more recent and from South Australia.

9 Household use of water

This chapter discusses the suite of activities undertaken to quantify the drivers of household use of water in metro Adelaide. The team was Mark Thyer (team leader), Nicole Arbon, Kym Beverley, Martin Lambert, Terry Cox (University of Adelaide), Darla Hatton MacDonald (CSIRO), and Karen Rouse, Andrew Wilkins, Nick Thomas, Grace Jennings, Steve Kotz, Tom Ryan, Lawrie McGing, Rob Daly (SA Water). SA Water purchased, installed and maintained the meters.

9.1 Purpose

Predicting the breakdown of water end-use within a household is essential for evaluating integrated urban water management systems, including rainwater and stormwater re-use. Currently little is known about the drivers of household end-use variability in a South Australian context. This project aimed to fill this knowledge gap by evaluating the key behavioural drivers of household water use in South Australia. A combination of high-resolution smart metering, household behavioural surveys, and flow trace analysis was used to determine the key drivers of household water use behaviour.

9.2 Method

The task was undertaken in stages:

- select representative households and install high resolution meters
- undertake household surveys of demographic attitudes and appliance characteristics
- undertake flow trace analysis of a two-week period to identify behavioural and appliance characteristics of indoor water use (shower/bath, toilet, washing machine, dishwasher, tap)
- analyse the water use drivers, by combining these data
- use these data within the Behavioural End-use Stochastic (BESS) model to estimate changes in water use due to the 2007-2009 drought, and then predict likely future water use due to changes in demand management - for use in the IUWM model.

The 150 owner-occupied, detached households selected for the project were representative of 65% of Adelaide's households, based on demographics, family composition and dwelling structure. Meters installed at these households in late 2012 recorded water use at the high resolution of 0.014 litres every 10 seconds.

9.3 Key findings

Household water use

Average study household water use for 2012/13 was 245 litres/person/day, 14% higher than the SA Water average for metro Adelaide. During the monitoring period (March 2013-February 2014) average study household water use was 289 litres/person/day, attributed to it being a hot summer. Total average indoor water use over the study period was 135litres/per/day (Table 14), 5% less than the 2009 usage reported in *Water for Good*.

Table 14 Results of the study showing disaggregation of indoor water use by appliance (litres/person/day)

Appliance	Use (litres/person/day)
Showers	48
Toilets	28
Washing machine	25
Taps	29
Bath and dishwasher	5
TOTAL	135

The survey revealed that households' perceptions of their end use proportions is highly unreliable, a practical implementation being that households need greater guidance and information about indoor water use so that they can identify cost-effective water savings opportunities.

Appliance efficiency

Appliance efficiency (rather than behaviour) was the primary driver for reductions in indoor water use (Table 15)

Table 15 Current and potential savings from using indoor water efficient appliances

Appliance	Currrent %	Potential saving (litres/person/day
Showers	43%	5.5
Toilets	35%	5.1
Washing machine (front loader)	55%	8.7
TOTAL		19.3

Seasonal water use

Preliminary results (as based on limited data) show a strong seasonal impact on water use from a winter mean of 153 litres/person/day to 498 litres/person/day in summer. As would be expected, seasonal water use increases with property/garden area, and reduces for lower income households. Interestingly, non-internally plumbed rainwater tanks and water conservation attitude did not appear to influence outdoor water use.

Peak water use

Peak day usage was approximately 2.8 times the mean day, driven mostly by hot, dry summer days. 20% of households contributed 50% of the total demand on peak days.

Predictive modelling – current and future usage

The BESS model predicted that approximately half of the 15% reduction in water use during the 2007-2009 drought could be attributed to uptake of water efficient appliances, with the remainder likely due to reductions on outdoor water use.

BESS was used to predict the impact of demand management, taking into account changes in household occupancy and uptake of water efficient appliances indoor, but assuming no change in behaviour or technology, or changes in outdoor use. Demand management was predicted to reduce residential water demand by 7% for 2013 and by 4% for 2014/15.

9.4 Summary

As a result of this study, questions about the key drivers of household indoor water use can be answered, including :

- Impact of water efficient appliances
  - reliable quantification of the reductions in household water use due to water efficient appliances
  - appliance efficiency (rather than behaviour) is the primary driver for reductions in indoor water (i.e. people do not take longer showers if the showerhead is more efficient)
  - efficient appliance uptake is approximately 50%
  - washing machines offer the greatest potential savings
  - savings are of the order of ~10% of indoor water use
- Impact of household age/composition/attitude on water use
  - different household types have significantly different water use behaviours
  - can identify opportunities for target household water savings programs
  - ‘pensioner effect’
  - over 55+ have water saving behaviour (shorter showers) and are more likely to perceive themselves as water conservers; however, they do not use less indoor use because of inefficient washing machines (~25% uptake of water efficient appliances) and higher toilet frequency

    - water saving opportunities are from uptake of efficient washing machines
- 'children effect/high income'
    - households with children are more likely to have higher incomes and higher shower duration, lower toilet frequency and more efficient washing machines (~75% uptake) top loaders
    - less likely to think of themselves as water conservers
    - water saving opportunities should target changing shower behaviour
- householders perceptions of their individual end-uses is poor
    - individual homes vary significantly from the average individual end-use statistics
    - difficult for households to know where their water saving opportunities are.

The inclusion of local data into the BESS model demonstrated that the model can provide reliable predictions of end use for houses that have similar demographics and household characteristics as the study households. Further development is required to improve transferability to locations with different demographics.

Longer term monitoring is required to confirm and refine the usage patterns and drivers identified through these studies. As the style of housing changes in urban centres (reduction in detached households, expansion in apartments and cluster housing), so too will usage patterns and attitudes to individual and communal water use. Extension of the methods developed and implemented in these tasks is required to get a more accurate representation of household water use today and into the future.

10 Simulation and optimisation modelling

This chapter describes the integrated urban water framework that was developed to incorporate, in the one modelling system, descriptions of supply and demand such that many different mixes of water source options could be simulated, and then optimised based on how best they met a set of agreed objectives. It covers both the simulation modelling of supplying from seven water sources plus demand management, potable and non-potable water demands, and the optimisation modelling of five of these water sources. The chapter concludes with presentation of some of the optimised results.

The study represents the work of two teams:

- the simulation team – Shiroma Maheepala (team leader), Fareed Mirza, Luis Neumann, Esther Coultas, Daniel Kinsman, Santosh Aryal (CSIRO), Nick Thomas, Rob Daly, Andrew Wilkins, Steve Kotz (SA Water), Guna Hewa (University of South Australia); Shaun Thomas, Ying He (EPA)
- the optimisation team – Graeme Dandy (team leader), Wenyan Wu, Angela Marchi, Holger Maier (University of Adelaide).

10.1 Purpose

From a planning perspective, the purpose of the project was to answer policy questions around the diversification of water supplies for metro Adelaide, anticipating future climate and urban growth, and future infrastructure investment priorities.

The research interest, and innovation, was to trial the applicability of the National Hydrological Modelling Platform's (NHMP) eWater Source as a suitable platform for the simulation of an urban water system, and to develop a framework that would support the identification of cost-effective, environmentally sustainable mixes of water sources to meet the needs of a large city, now and in the foreseeable future.

10.2 Method – simulation modelling

A modelling tool that could inform city-scale integrated water cycle management plans was developed, as such a tool is essential for characterising the components of the urban water system (supply, demand, stormwater harvesting, wastewater, receiving waters) necessary to be able to explore alternate mixes of sources, and multiple demand and harvesting options. An initial investigation was conducted to assess the feasibility of using Source. Despite its not having been designed specifically for the desired purpose, Source had the advantages of flexibility, plug-in functionality, and a customised optimisation tool, Insight.

Schematisation of metro Adelaide

Conceptualisation of the system was based on characterising supply and demand such that policy questions about sourcing water to meet demand could be addressed. The characterisation of the five sources – River Murray, Mt Lofty Ranges catchments, Adelaide desalinisation plant, (recycled) wastewater and stormwater is given in Table 16.

Table 16 The five water sources, as they were characterised for the purposes of modelling

Source	Characterisation
River Murray	Three pipelines - Mannum-Adelaide, Murray Bridge and Swan Reach Stockwell, with capacities of 364 ML/day, 510 ML/day and 79 ML/day respectively
Mt Lofty Ranges catchments	Surface water storages and weirs aggregated to three storages (Gawler, Torrens and Onkaparinga) with a combined capacity of 171 GL.
Adelaide desalination plant	As an infinite capacity storage, with a release capacity of 300 ML/day
Recycled wastewater	Three wastewater treatment plants – Bolivar, Glenelg and Christies Beach, with plant capacity of 60,225 ML/year, 21,900 ML/year and 16,425 ML/year respectively. Treated wastewater not reused assumed to be discharged to coastal waters
Stormwater	The 70 existing or proposed harvesting schemes were lumped into 25 schemes based on their hydrologic connectivity. All schemes were assumed to use aquifer storage and recovery (ASR)

Figure 3 is a schematic diagram of how the system was conceptualised for modelling. The study area was spatially disaggregated into three demand zones – north, central and south – with stormwater and wastewater collected via a pipe network and discharged to coastal waters (wastewater being treated prior to discharge). Each demand zone has four demand nodes to represent residential and non-residential potable and non-potable demands. Water supply was characterised as per the information in Table 16.

The simulation period was 31 years (January 1982 to December 2013), and the model timestep was monthly. The simulation was run for three different periods – 2013, 2025 and 2050, the latter requiring preparation of data describing possible population and climate futures.

The details of the model construction, together with data preparation and model assumptions, are described in Maheepala et al. (2014).

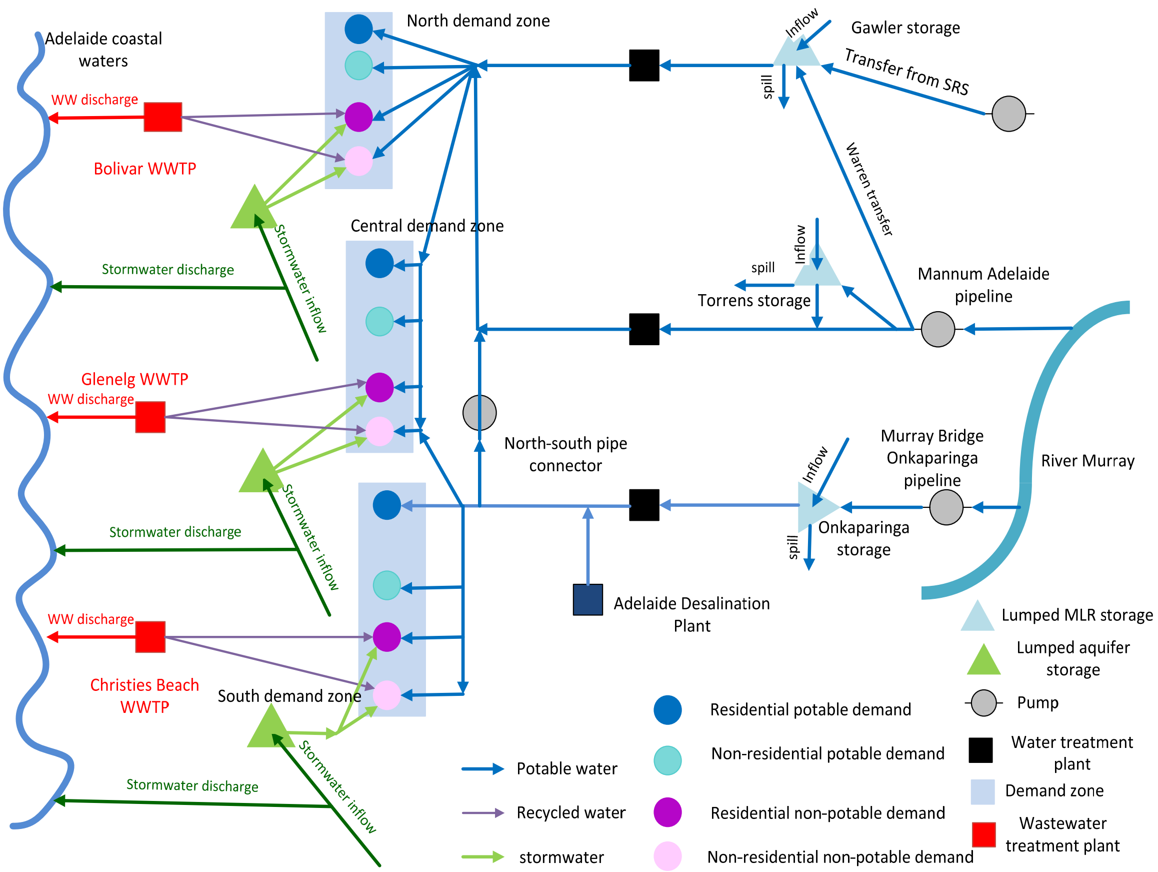

Figure 3 Schematic diagram of the metro Adelaide urban water system case study showing supply from the River Murray, Mt Lofty Ranges catchments, Adelaide desalination plant, wastewater and stormwater sources to residential and non-residential, potable and non-potable demands. This figure is provided at landscape scale in Appendix C

10.3 Method – multi-objective optimisation modelling

Searching for a set of suitable mixes of water that met demands under current (2013), 2025 and 2050 conditions, requires the setting of objectives, constraints and decision variables that drive the search algorithms. For the case study, potential objectives and constraints were workshopped with stakeholders, and decision variables then chosen to control the amount of water that could be supplied from the available resources. These are set out in Table 17.

Table 17 Objectives, constraints and decision variables to drive the search algorithms

	Term
Objective	minimise the cost of supply[4]
Objective	minimise energy consumption[5]
Objective	maximise volumetric reliability of the non-potable component of the system supply
Objective	minimise total stormwater and wastewater discharge to coastal waters
Constraint	time supply reliability of the potable component of the system demand be 99.5%
Constraint	environmental flow releases from reservoirs be met
Constraint	monthly target volumes of the storages in the Mt Lofty Ranges catchment be met
Constraint	maximum amount of water extracted from the River Murray be limited to 650 GL over any consecutive five year period
Decision variable	amount of water that can be drawn from Mt Lofty Ranges catchment, subject to the constraints on monthly target volumes and environmental flow releases
Decision variable	amount of water that can be drawn from the River Murray from each pipeline, subject to extraction and pipe capacities;
Decision variable	amount of water that can be drawn from the Adelaide Desalination Plant, subject to its maximum capacity
Decision variable	stormwater schemes to be implemented (i.e. on/off for 25 schemes)
Decision variable	amount of recycling capacity of WWTPs to be increased, subject to their maximum treatment capacity

The simulation model provided the volumes of water from the different sources such that the optimisation algorithm could identify efficient solutions. The optimisation was implemented using the Insight module within Source. Using the version that was used for setting up the simulation model, the optimal priority order could not be determined using the optimisation algorithm – this was countered by being able to take into account the stakeholders' preferences directly. Three priority sets were thus identified (Table 18). Priority set #1 reflected the community's desire to use harvested stormwater and recycled wastewater for non-potable purposes, if possible, as elicited in survey by Mankad et al. (2013) and ; priority set #2 reflected a desire to minimise operating costs; and priority set #3 was based on preferences expressed by the focus groups as part of this programme and reported in Chapter 4 Community preferences and perceptions, with one change – the groups ranked desalinated water ahead of water from the Mt Lofty Ranges catchments – this was reversed as it was government policy to only use the desalination plant as an emergency source in droughts.

[4] Calculated as the total present value of the life cycle cost of infrastructure over 25 years with a discount rate of 6%

[5] Calculated as the total present value of energy consumption, including embodied energy, over 25 years

Table 18 Priority of water sources, based on stakeholders' preferences. The lowest number has the highest priority

Priority Set	Priority order for potable use	Priority order for non-potable use[1]
#1	1. Mt Lofty Ranges catchment 2. River Murray 3. Desalinated water	1. Harvested stormwater 2. Recycled wastewater 3. Mt Lofty Ranges 4. River Murray 5. Desalinated Water
#2	1. Mt Lofty Ranges catchment 2. River Murray 3. Desalinated Water	1. Mt Lofty Ranges catchment 2. River Murray 3. Harvested stormwater 4. Recycled wastewater 5. Desalinated Water
#3	1. Mt Lofty Ranges catchment 2. Desalinated Water 3. River Murray	1. Harvested stormwater 2. Recycled wastewater 3. Mt Lofty Ranges catchment 4. Desalinated water 5. River Murray

Source: Table 40, Maheepala et al. (2014)

Optimisation runs were carried out for each scenario (2013, 2025 and 2050) for priority sets #1 and #2, and with two different random seeds[6]. 400 supply solutions were obtained for each scenario[7]. All these solutions complied with the constraint on the time-based reliability of the potable water supply (>99.5%).

To determine which solution/s represented the best compromise between the objective, a technique of compromise programming[8] and stakeholder preferences were used.

10.4 Results

When reading the following results, it must be remembered that they are for a case study that is based on a simplified conceptualisation of metro Adelaide. They are affected by limitations in the algorithm parameterisation and the quality of the input data, much of which was derived from the literature, not from observed local data. For these reasons, it is the discussion of the alternative mixes, rather than the absolute values, which are of most interest. Indeed, the absolute numbers are merely a means to an end, and necessary for the simulation and optimisation modelling.

Three sets of results are presented, all of which have been extracted from Maheepala et al (2014):

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[6] The effect of the different random seeds is discussed in Maheepala et al. (2014), p103

[7] These are listed in Appendix 3 of Maheepala et al. (2014)

[8] Compromise programming was used for this purpose. It identifies the solutions that are closest to the ideal solution (which would simultaneously minimise total cost, operating energy, discharge to the Gulf and maximise non-potable volumetric reliability).

- optimised solutions for 2013
- optimised solutions for 2050
- a subset of these solutions, called the preferred solutions, based on their 'match' against the optimisation objectives.

The system optimisation did not include roof/rainwater tanks or demand management. A small study was undertaken, using one of the solutions for the 2013 and 2050 scenarios, to assess their impact.

10.4.1 Optimal solutions for 2013 and 2050

In all solutions there was a trade-off between cost and energy consumption; cheaper solutions having significantly high energy consumption – they save money on the capital costs of new infrastructure. There was also a trade-off between total cost and discharge to the Gulf – less expensive solutions having larger discharges. In general, as water from Mount Lofty Ranges catchments and the River Murray are less expensive than stormwater and recycled wastewater, the cheapest solutions exploit the first two sources. Using recycled wastewater tended to be favoured over the use of stormwater due to their different operational costs and by the different seasonal availability of the two sources. Figure 4 shows a plot of total costs vs total discharges and is an example of the style of presentation of these data in Maheepala et al. (2014).

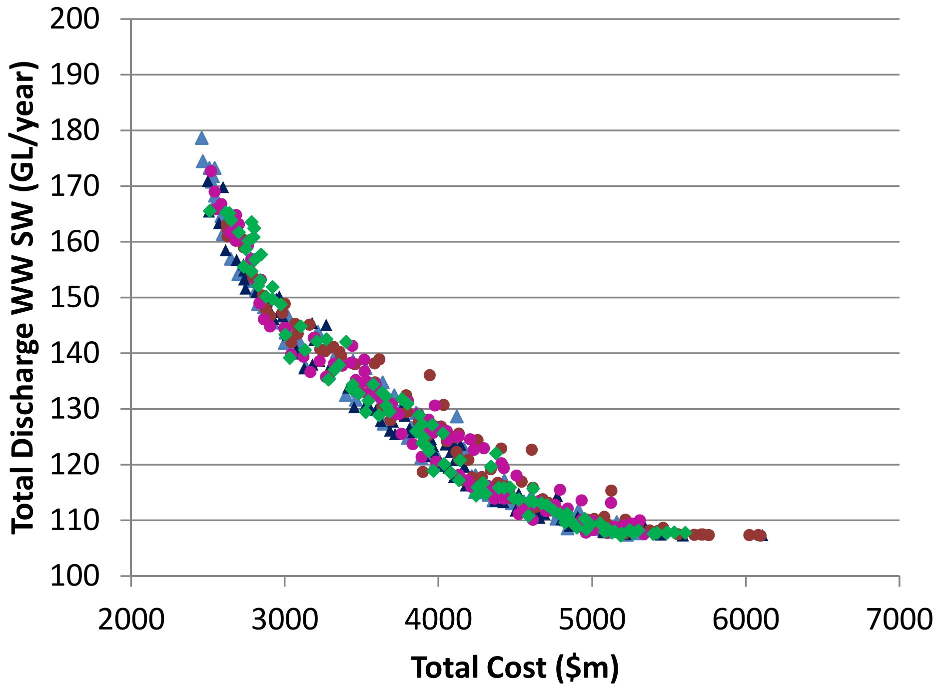

Figure 4 Relationship between total costs and total discharges of the solutions for the 2013 scenario, combining all priority sets (#1, #2 and #3). Adapted from Figure 55 in Maheepala et al. (2014)

Figure 5 shows the optimal solutions for the 2013 scenario. Overall the solutions supplied about 50% of demand from the Mount Lofty Ranges catchments (the cheapest source), then about 10–40% from the River Murray, then recycled wastewater. The maximum use of stormwater was about 10% while desalinated water was used on only a few occasions to meet potable demand in drought conditions. It should be noted that many solutions use a large volume of wastewater and stormwater as their use reduced discharge to the Gulf. Using Priority set #2, solutions used more water from the Mt Lofty Ranges catchments and the River Murray than with priority set #1.

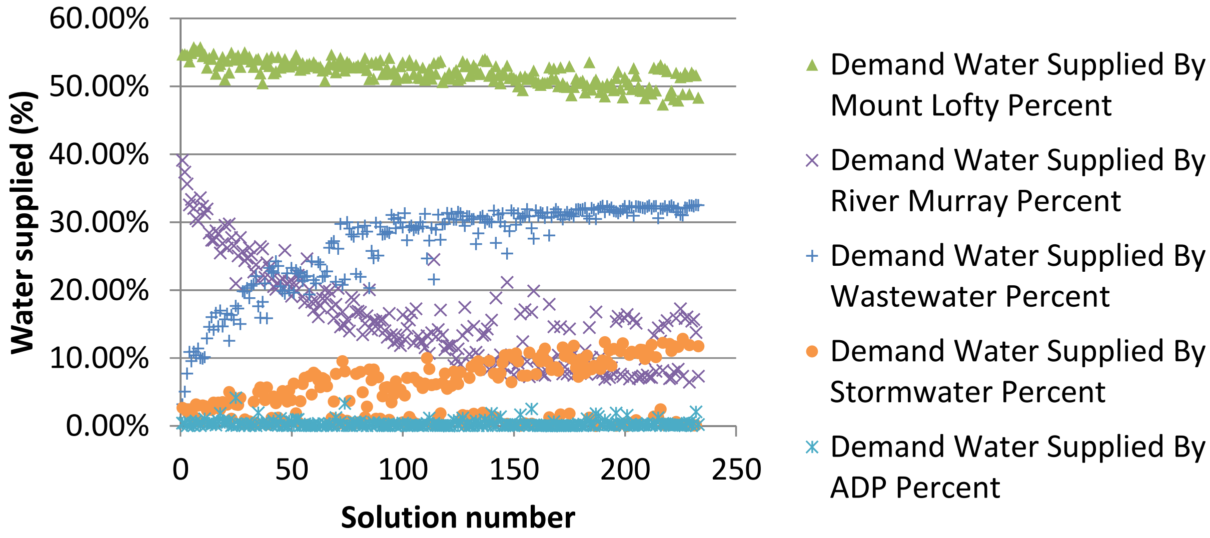

Figure 5 Percentages of demand supplied by Mount Lofty Ranges catchments, River Murray, recycled wastewater, stormwater, and desalinated water (ADP) for the 2013 scenario with priority sets #1 an #2 (Source: Figure 61, Maheepala et al (2014))

Solutions for 2025 and 2050 scenarios followed similar trends to the 2013 scenario. Cost ($3000m-$7000m) and energy consumption (5500-8000 GWh) are higher, due to the larger demand, while discharges to the Gulf are similar to the 2013 scenario. Figure 6 shows that the cheapest solutions for the 2050 scenario use more River Murray water than in 2013 (50% compared to 40%) and that supply from Mt Lofty Ranges catchments is almost constant at about 35%. This is likely to be because that is the proportion of demand that can be supplied from Mt Lofty Ranges catchments.

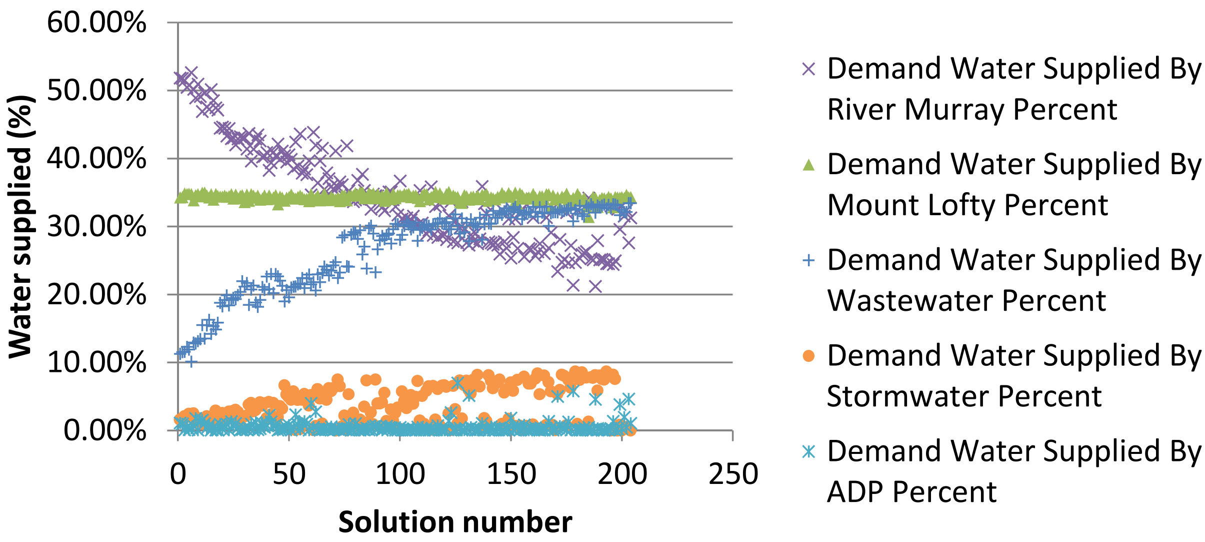

Figure 6 Percentages of demand supplied by Mount Lofty Ranges catchments, River Murray, recycled wastewater, stormwater, and desalinated water (ADP) for the 2050 scenario with priority sets #1 an #2 (Source: Figure 73, Maheepala et al (2014))

10.4.2 Preferred solutions for 2013 and 2050

Table 19 lists six (6) preferred solutions for 2013 and 2050, selected for how well they met the optimisation objectives of minimising cost, energy and discharge, while maximising volumetric reliability of non-potable demand.

- Solution 1 minimises total cost
- Solution 76 minimises total energy
- Solution 44 maximises volumetric reliability of non-potable system demand
- Solution 233 minimises discharge to the Gulf
- Solution 64 is the 'best' compromise solution when cost, reliability and discharge objectives are considered (i.e. not energy)
- Solution 97 is the 'best' compromise solution when all four objectives (cost, energy, reliability and discharge) are considered.

The percentage mix of sources for each preferred solution is shown in Figure 7 and capital and operational costs for each preferred solution in Table 20.

Table 19 Preferred solutions for the 2013 scenario, ordered from lowest to highest total cost. The boxes identify the lowest cost, energy and discharge, and highest reliability, solution (Source: adapted from Table 41 in Maheepala et al (2014))

#	Total cost $M	Total energy GWh	System demand non-potable volumetric reliability (%)	Total system discharges (storm and waste waters) to the Gulf GL/y
1	2459	5045	100.00%	179
44	3123	3887	100.00%	139
64	3453	4088	99.97%	130
76	3570	3453	99.91%	133
97	3798	3646	99.96%	125
233	6111	4492	99.65%	107

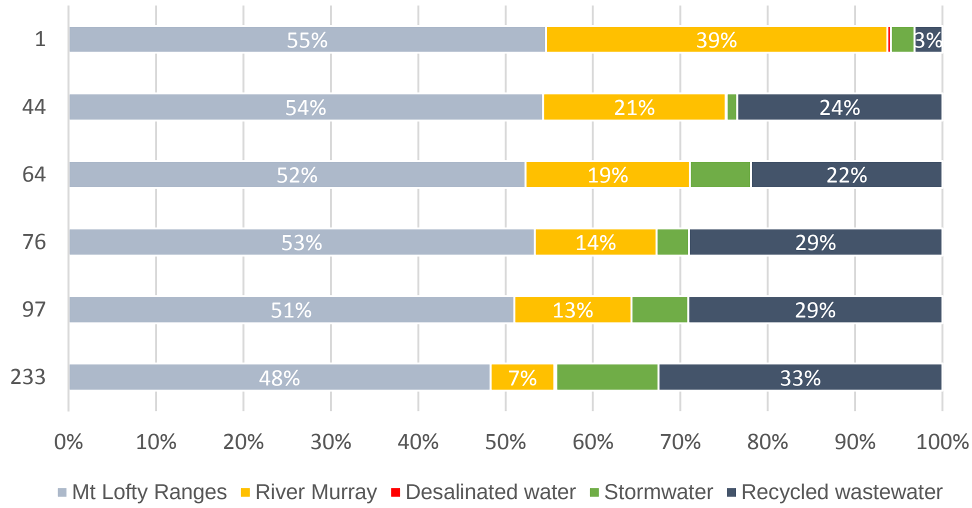

Figure 7 The supply mix from each source (as a percentage of the total supply of ~172 GL/y) for each of the preferred solutions for the 2013 scenario (info from Table 42 in Maheepala et al (2014))

Table 20 Capital and operational costs for each source for the 2013 preferred solutions (source Table 44 in Maheepala et al (2014))

			Capital cost		Operational cost				
#	PV capital cost	PV op cost	S'water	W'water	Mt Lofty Ranges	River Murray	Desalinated water	S'water	W'water
	$M	$M	$M	$M	$M/y	$M/y	$M/y	$M/y	$M/y
1	78	2391	40	29	23	33	31	5	96
44	547	2576	159	388	21	19	30	7	124
64	818	2635	445	373	21	17	30	15	123
76	995	2575	135	859	21	14	30	5	131
97	1160	2638	350	810	20	13	30	10	133
233	3416	2695	1354	2062	19	8	30	18	137

A similar exercise was carried out for the 2025 and 2050 scenarios. As would be expected, water withdrawn from all sources (except the Mt Lofty Ranges catchments) was greater than for the 2013 scenario due to increased demand. In terms of percentage of demand supplied, supply from Mt Lofty Ranges catchments decreases in 2050. The preferred (compromise) solutions are listed in Table 21.

- Solution 1 minimises total cost
- Solution 6 maximises discharge
- Solution 67 is the 'best' compromise solution when cost, reliability and discharge (i.e. not energy) are considered
- Solution 99 minimises total energy
- Solution 101 is the 'best' compromise solution when all four objectives (cost, energy, reliability and discharge) are considered
- Solution 108 maximises reliability
- Solution 196 minimises reliability
- Solution 197 minimises discharge.

The percentage mix of sources for each preferred solution is shown in Figure 8 and capital and operational costs for each preferred solution in Table 22.

Table 21 Preferred solutions for 2050, ordered from lowest to highest cost. The lowest total energy and discharge are identified (source: adapted from Table 45 in Maheepala et al (2014))

#	Total cost $M	Total energy GWh	System demand non-potable volumetric reliability %	Total system discharges (storm and waste waters) to the Gulf GL/year
1	3165	7390	99.98%	164
6	3240	7365	100.00%	164
67	4196	6440	100.00%	125
99	4788	5893	99.96%	120
101	4859	6046	100.00%	114
108	4996	6208	100.00%	115
196	6575	6637	99.86%	99.2
197	6576	6345	99.87%	98.8

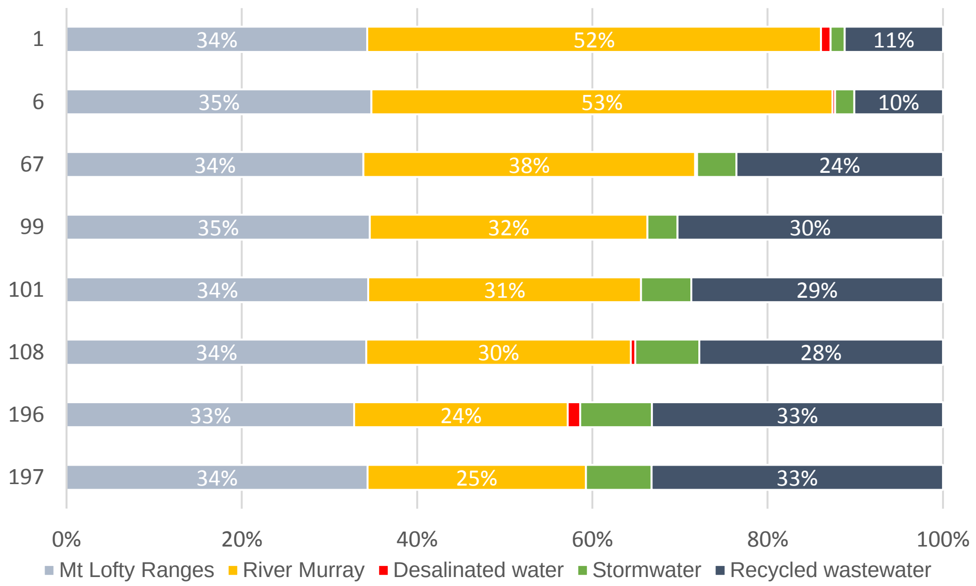

Figure 8 The supply mix from each source (as a percentage of the total supply of ~212.5 GL/y) for each of the preferred solutions for the 2050 scenario (info from Table 46 in Maheepala et al (2014))

Table 22 Capital and operational costs for each source for the preferred solutions for the 2050 scenario (source Table 48 in Maheepala et al (2014))

			Capital cost		Operational cost				
#	PV capital cost	PV op cost	S'water	W'water	Mt Lofty Ranges	River Murray	Desalinated water	S'water	W'water
	$M	$M	$M	$M	$M/y	$M/y	$M/y	$M/y	$M/y
1	69	3095	14	55	19	53	32	4	134
6	154	3087	115	38	20	54	31	5	132
67	913	3283	315	598	19	40	30	11	156
99	1510	3279	192	1318	19	34	30	6	168
101	1540	3320	420	1120	19	33	30	11	166
108	1697	3298	730	968	19	33	31	12	164
196	3174	3400	1009	2166	19	27	33	14	173
197	3204	3372	1034	2169	18	28	30	15	173

10.4.3 Impact of harvesting roof/rain water and demand management

Table 23 and Table 24 show the results of including rainwater tanks and demand management as supply sources.

Table 23 Impact of having roof/rainwater harvesting (rainwater tanks) and demand management for solution #1 of the 2013 scenario (adapted from Table 49 in Maheepala et al (2014))

Solution ID	Total cost $M	Total energy GWh	Non-potable volumetric reliability %	Total discharge GL/y	Comments
1	2459	5045	100%	179	Minimum cost and maximum discharge
1/RWT	4623	5927	100%	170	21.5 GL/year supplied by RWTs
1/DM	2449	2780	100%	173	8.7 GL/year water savings with DMs
1/RWT & DM	4616	3711	100%	165	30.2 GL/year supplied by RWTs and DM

Table 24 Impact of having roof/rainwater harvesting (rainwater tanks) and demand management for solution #1 of the 2050 scenario (adapted from Table52 in Maheepala et al (2014))

Solution ID	Total cost $M	Total energy GWh	Non-potable volumetric reliability %	Total discharge GL/y	Comments
1	3165	7390	99.98%	164	Minimum cost and maximum discharge
1/RWT	6507	8660	99.97%	154	33.2 GL/year supplied by RWTs
1/DM	3107	6774	99.97%	157	10.9 GL/year water savings with DMs
1/RWT & DM	6448	8092	99.96%	148	44.1 GL/year supplied by RWTs and DM

These indicate that the use of rainwater tanks would not be a preferred supply solution, if the preference was to minimise the total cost or the total energy consumption. The impact on total demand due to adoption of demand management was negligible, in both 2013 and 2050.

In summary, the use of rainwater tanks could:

- reduce reliance on other sources by reducing total demand by about 12% in 2013 and 16% in 2050
- reduce discharge to the Gulf (about 5%) but at a large increase in cost;

In summary, the use of demand management could:

- reduce reliance on the current potable water sources by about 5%
- reduce energy consumption by about 45% in 2013 and by 8% in 2050.

10.5 Summary

The modelling work described in this chapter represents a significant part of the overall project, as it required the collation and derivation of many datasets, many discussions with stakeholders to get agreement on the system conceptualisation and how to present and interpret results, many model runs to calibrate the models (to be as realistic as possible given that much of the data were not locally observed data), and then many optimisation runs to explore the multiple source solution space from a range of perspectives. Specific conclusions on the model implementation include:

- The Source platform (Source catchment, Source schematic and Insight) proved to be sufficiently flexible and functional to adequately represent a complex multi-source integrated urban water system. This is a significant result for the National Hydrological Modelling Platform and unified water resource modelling and management in Australia and overseas
- While not a fully operational modelling system for metro Adelaide, due to assumptions that needed to be made, quality and relevance of data, and time constraints resulting in focussing the optimisation on a small set of solutions, the IUWM simulation and optimisation models developed within this project is sufficiently powerful to address questions about suitability of alternate water sources, and the effect of incorporating user preferences when sourcing water.

Specific conclusions in terms of results include:

- The Mount Lofty Ranges catchments are generally the preferred source for potable water
- If minimising cost is the priority, then River Murray water is preferred for non-potable use

- If reducing any adverse impact of water discharged to Gulf St Vincent is the priority, then treated wastewater and harvested stormwater are preferred for non-potable use, with the former (i.e. treated wastewater) being more cost effective than the latter
- Rainwater tanks have their place and can reduce demand from other sources by up to 12%; however they are not cost effective and have high energy consumption
- In-house water efficient appliances have the potential to reduce total water consumption by about 5% (noting discussion in Chapter 9 about market saturation)
- Minimum energy solutions do not equate to minimum cost solutions, and vice versa.

11 Commentary on mix solutions from social and governance perspectives

This chapter provides some commentary on the results that emerged from the optimisation modelling, from social and governance perspectives. Social preferences, as reported in Chapter 4, were not used to constrain the optimisation – neither were governance or institutional issues as discussed in Chapter 5 – as the elicitation of these preferences was not exhaustive, and preferences can change significantly due to increased knowledge, incentives, etc.

The community perspective commentary was provided by Leonard et al. and is not published elsewhere. The institutional commentary is drawn from Keremane et al (2014).

11.1 From a community view perspective

A comparison of three of the 2013 solutions (lowest cost (1), and the 'best' compromises (64 and 97)) in terms of the community views expressed in the focus groups suggests that the lowest cost solution (1) would not be seen as desirable. While it may be attractive to businesses and low income earners for that reason, this solution had a very high use of the River Murray and maximised the discharge to the Gulf, both of which were seen negatively by most participants.

The 'best' compromise (64) when considering cost, reliability and discharge uses much less water from the River Murray with reduced discharge to the Gulf, achieved mainly by the increased use in wastewater and partly by increased use of stormwater. Compared with the least cost solution (1), this mix is much more in keeping with the major themes of protecting vulnerable ecosystems and maximising the use of under-utilised sources.

The 'best compromise (97) which also considers energy continues the trend to reduce River Murray use which is achieved mainly by an increased use of wastewater. Such a solution would greatly increase the cost but it would minimise discharge to the Gulf. Thus it maximises the protection of vulnerable ecosystems and maximises the use of under-utilised sources. This solution is likely to appeal to people at the high end of the Water Thrift scale, who were involved in local water saving urban design (WSUD) schemes. It might however alienate those at the low end who were concerned about a waste of money through high cost ventures and a waste of existing infrastructure.

The three solutions for 2050 (1, 101,197) also represented respectively the minimum cost, compromise, and minimum discharge but maximum cost solutions. These three solutions showed the same general pattern as the 2013 solutions. Cheaper solutions use more River Murray water; more expensive ones use more wastewater; and the most expensive use more stormwater. However there were some differences between all the 2013 and the

2050 solutions. Less Mt Lofty water is used in all solutions in 2050 than in 2013 because of the expectation of lower rainfall with climate change. All solutions suggest that the big increases to cover population growth by 2050 will come from the River Murray. The most expensive solution in 2050 used more wastewater, less stormwater and more River Murray water than the most expensive solution for 2013. Focus group discussions suggest the high reliance on the River Murray would not be popular.

All the solutions made minimal use of the desalination plant which, on one hand, would appeal to those who were concerned about the marine environment around the plant. On the other hand, with the strong discourse of avoiding waste, including waste in infrastructure, there might be community criticism. There was appreciation of the desalination plant as 'an insurance policy' so minimal use might be acceptable in those terms. However when the suggested supply from the plant is so minimal, it would seem more efficient to keep it in standby mode outside of drought conditions.

11.2 From an institutional/governance perspective

The focus of interest from a governance perspective is on the 'new' sources of water – the desalination plant, recycled wastewater and stormwater harvesting and reuse. All solutions show a preference for wastewater over stormwater. Costing for both sources include cost of pipes, which is significant for both types of water. Energy costs for wastewater are more significant as it has to be treated to non-potable or potable standards. It is noted that these costs are based on multiple assumptions, and any changes in those could change the scenarios.

While the management of stormwater has changed over the years and now reflects values of conservation, pollution mitigation, ecological restoration and urban landscape improvement, not a great deal has changed in its governance. The governance of wastewater is tightly held and hence easier to manage than stormwater. Hence, wastewater appears to be a better solution from a governance perspective.

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Appendix A Project people and structure

A.1 Project team

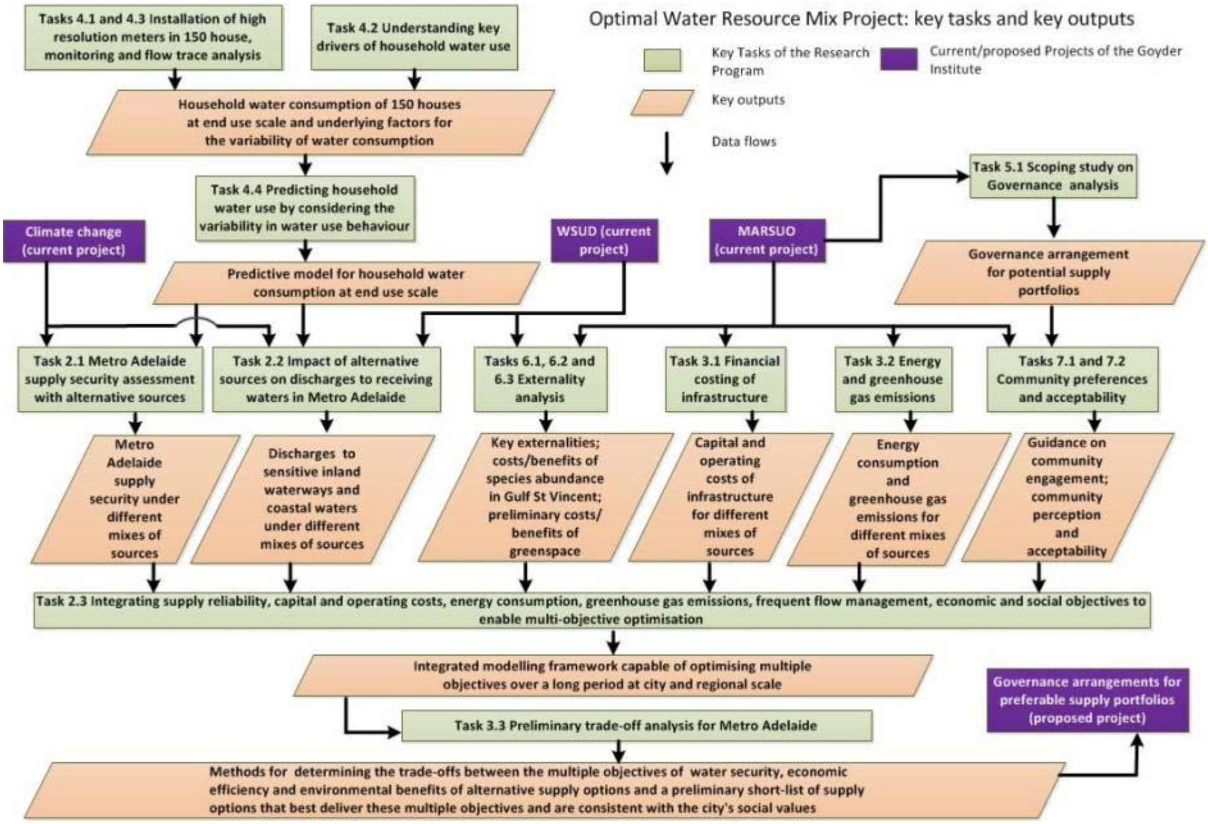
Team	Members
Task 1, Stakeholder engagement	Kathryn Bellette* (Flinders University)
Task 2, simulation modelling	Shiroma Maheepala*, Fareed Mirza, Luis Neumann, Santosh Aryal, Esther Coultas, Daniel Kinsman (CSIRO) Nick Thomas, Rob Daly (SA Water) Guna Hewa (Uni SA) Shaun Thomas, Ying He (EPA)
Task 3, optimisation framework	Graeme Dandy*, Wenyan Wu, Angela Marchi, Holger Maier (Uni Adelaide)
Task 4, household water use	Mark Thyer*, Nicole Arbon, Kym Beverley, Martin Lambert, Terry Cox (Uni Adelaide) Darla Hatton MacDonald (CSIRO) SA Water (installation of h'hold metering and assistance with survey)
Task 5, institutional and governance issues	Jennifer McKay*, Ganesh Keremane, Zhifang Wu, Vaso Caspro (Uni SA)
Task 6, economic analysis	Darla Hatton MacDonald*, John Kandulu (CSIRO) Morgan Schebella (student, Uni SA) Sean Connell, Bayden Russell (Uni Adelaide)
Task 7, social attitudes	Rosemary Leonard*, Andrea Walton, Carol Farbotko, Aditi Mankad, Melissa Green, Anneliese Spinks, Sarah Malkin (CSIRO)
Task 8, project management	Susan Cuddy*, Darran King, Marion Peters (CSIRO)

* Task leader

A.2 Project reference panel

Organisation	representative
AMLR NRM Board	Alan Ockenden until 2013, then Steve Gatti
SA Water	Karen Rouse, Grace Jennings (Steve Kotz proxy) until mid 2013, then Grace Jennings and Steve Kotz
Dept Environment, Water and Natural Resources	Steve Morton (Martin Allen proxy)
Environment Protection Authority	Andrew Solomon (Shaun Thomas proxy)
Dept Planning, Transport & Infrastructure	Sharon Wyatt
Local Government Association (LGA)	Steve Hodge (Adrian Sykes proxy)

A.3 Project structure, showing the dependencies between tasks



Appendix B Terminology

B.1 Detailed descriptions of the seven water sources and demand management, including details of treatments undertaken, use post-treatment, potential hazards and associated risk, and side-benefits

Short definition	Treatment undertaken	Use post-treatment (at present, and potential in the future)	Potential hazards and associated risk[9]	Side benefits
Mount Lofty Ranges catchment				
The runoff water from rain falling over the Mount Lofty Ranges catchment drains into reservoirs A reservoir is a natural or artificial body of water used as a storage for water supply	Treatment is undertaken at water treatment plants downstream of the Mt Lofty Ranges service reservoirs Drinking water quality is managed by a multi-barrier approach and preventative measures which include catchment management, source water management, treatment, disinfection and a closed supply system	Currently drinking water (water fit for human consumption). Supplied in accordance with Australian Drinking Water Guidelines and Safe Drinking Water Act This water is used for both drinking and non-drinking purposes at domestic, commercial and industrial scales	Microbiological risks (E.g. *E. coli*, *Cryptosporidium*) Chemical risk (e.g. pesticide, nutrients) Biological (e.g. algal by-products) in reservoirs Seasonal variability (low inflows in a 'dry' year) Climate change – potential for future reduction in winter inflows (security) Risk of over extraction if not managed	Comparative costings and energy usage/greenhouse gas emissions of water sources will be provided when relevant report has been finalised.
River Murray				
River Murray water pumped to reservoirs to supplement Mt Lofty Ranges catchment inflows. River Murray water can also be used to supply a treatment plant directly	Treatment is undertaken at water treatment plants downstream of the reservoirs and pipelines The water quality is managed by a multi-barrier approach which includes catchment management, source water management, treatment, disinfection and a closed supply system	Currently drinking water (water fit for human consumption). Supplied in accordance with Australian Drinking Water Guidelines and Safe Drinking Water Act This water is used for both drinking and non-drinking purposes at domestic, commercial and industrial scales	Microbiological risks (E.g. *E. coli*, *Cryptosporidium*) Chemical risk (e.g. pesticide, nutrients) Algal blooms (river or reservoir) Low water availability in the Murray (quantity) Variation in quality of River Murray Water Risk of over extraction if not managed	Provides water to offtakes along pipelines (including Adelaide Hills townships) National political awareness of Murray River health Substituted for Mt Lofty Ranges catchment water to enable delivery of Environmental flows in Mt Lofty Ranges

[9] Risks include those relating to water quality, volume, and safety infrastructure

Short definition	Treatment undertaken	Use post-treatment (at present, and potential in the future)	Potential hazards and associated risk[9]	Side benefits
Groundwater				
Water contained by rock beneath the earth's surface, known as aquifers. Water in aquifers is usually accessed by bores, wells or springs	Treatment varies depending on groundwater quality and the intended use, e.g.: no or minimal treatment where groundwater quality is fit for purpose, such as for many irrigated agriculture uses treatment to improve quality of groundwater (e.g. to reduce water hardness, or improve water colour or reduce odour to improve aesthetics, etc.) treatment to reduce salinity if it is naturally too high for the intended use (e.g. for use in mining and drinking ventures in parts of SA and elsewhere) disinfection (e.g. for relatively high quality uses)	Current uses in metropolitan and outer metropolitan Adelaide includes watering of parks and other large irrigated open spaces such as golf clubs, garden and toilet flushing, maintaining water levels of aesthetic lakes, horticultural uses, grape growing, and some commercial uses (including 'natural' groundwater which with additional treatment is used for the production of bottled drinks etc)	Potential water quality risks in urban and peri-urban environments include: Microbiological risks (E.g. *E. coli*, *Cryptosporidium, viruses*) Chemical risk (e.g. industrial contaminants, pesticide, nutrients) Salinity in some groundwater systems may require some desalination to use. Potential risk to soil from long term irrigation with saline water if not managed Potential volume-related risks include: Seasonal Variability in availability (low inflows in a 'dry' year (for aquifers with quick response times and those fortified with artificial injection of stormwater) Seasonal Variability in demand (low demand may require reduced artificial injection of stormwater to prevent rising groundwater Climate change – long term reductions in rainfall may reduce groundwater recharge Economic risks In some circumstances, such as where aquifer characteristics can vary widely over short distances, injection or extraction rates from aquifers will not be known until wells are drilled. As a result there is a financial risk for investors in such areas The knowledge of the life of injection and recovery wells is not yet well established, posing a risk to aquifer storage and recovery investors Environmental risk Risk of over extraction if not managed	Artificial recharge schemes can sometimes be designed to provide side benefits (e.g. associated wetlands provide local amenity, water quality improvement and flood mitigation)

Short definition	Treatment undertaken	Use post-treatment (at present, and potential in the future)	Potential hazards and associated risk[9]	Side benefits
Seawater (desalinated)				
Seawater treated to convert highly saline water into water suitable for human consumption (drinking water)	Treatment and disinfection at Adelaide Desalination Plant (ADP)	Drinking water supply This water is used for both drinking and non-drinking purposes at domestic, commercial and industrial scales	Large scale infrastructure requires significant upfront investment	Climate independent Very high quality
Recycled wastewater				
Recycled Wastewater (treated sewage) is the end product of a wastewater treatment plant that is treated to a standard that is fit for purpose	Fit for purpose treatment depending on end use. Currently based on the Australian Guidelines for Water Recycling (AGWR) which takes a systematic 'risk management approach' to assess and mitigate risks, thus maintaining public health	Currently non drinking water (with a range of uses from piped supply to household for garden watering and toilet flushing through to agriculture and industrial processes) Potential for drinking water supply (not current policy) either: Directly – treated to drinking water standard and supplied directly to end users, or Indirectly – treated to fit for purpose standard and mixed with other source water. This water can however be treated to a higher quality to meet AWQG for other uses for direct and indirect use	Microbiological risks (E.g. *E. Coli*, *Cryptosporidium, viruses*) Chemical risk (e.g. pesticide, nutrients) High salinity in some catchments	Reduction in volumes (and contaminants e.g. sediment and Nitrogen) discharged to coastal waters and associated environmental benefits Increased water awareness from recycled water users Users may be exempt from water restrictions Nutrient reuse. Nitrogen and phosphate can be used for agriculture reducing requirements for additional fertiliser Climate independent

Short definition	Treatment undertaken	Use post-treatment (at present, and potential in the future)	Potential hazards and associated risk[9]	Side benefits
Stormwater				
Rainwater that runs off all urban surfaces such as roofs, pavements, car parks, roads, gardens and vegetated open spaces	Fit for purpose treatment depending on end use. Currently based on the Australian Guidelines for Water Recycling (AGWR) which takes a systematic 'risk management approach' to assess and mitigate risks, thus maintaining public health Typically temporary detention in an artificial pond or constructed wetland which allows partial settlement and filtering of suspended matter and a partial reduction in nutrients and some other pollutants usually found in stormwater	Current uses include non-drinking uses such as watering of parks and reserves, some industry applications that do not require high-quality water, and toilet flushing In some areas, wetland-treated stormwater is also injected into underground aquifers for temporary storage prior to extraction for various non-drinking uses (see 'Groundwater' above)	Risks include quality (health), volume (security), Environmental and Safety (infrastructure) Microbiological risks (E.g. *E. Coli*, *Cryptosporidium*) Chemical risk (e.g. pesticide, nutrients) Biological (e.g. contamination from algae) in reservoirs While these risks are qualitatively similar to those listed above for reservoirs, the potential hazards for urban stormwater will differ, and be catchment/land-use specific Water security risks include: Seasonal variability in supply (low inflows in a 'dry' year) and demand (implications for storage) Climate Change – potential for future reduction in winter inflows (security) Potential impact if the resource is later exploited further upstream in catchments (note however that State legislation seeks to prohibit impacts on downstream users) Public safety wetlands/pond systems require suitable design and ongoing management to mitigate potential hazards such as risk of drowning, mosquito and feral animal habitats and accumulation of contaminated sediments) Risk of over extraction if not managed	Stormwater harvesting schemes can sometimes be designed to provide other benefits (e.g. stormwater wetlands for water quality improvement and amenity, flood mitigation) Potential for implementing local 'water-sensitive urban design' solutions for capturing and using stormwater runoff (e.g. streetscape 'biofilters', 'rain gardens' etc.), as well as larger-scale wetlands that have typically been employed to date in Adelaide Development scale solutions may in specific situations help to maintain the effectiveness of off-site minor stormwater drainage systems, or mitigate the need to upgrade offsite stormwater drainage

Short definition	Treatment undertaken	Use post-treatment (at present, and potential in the future)	Potential hazards and associated risk[9]	Side benefits
Rainwater/roof water				
Water collected from the roofs of houses or other buildings	Typically (in domestic settings) none or minimal (e.g. coarse filtering and/or mosquito mesh screen) prior to storage for use Or formal filtration systems are installed associated with domestic plumbing	Current uses include drinking (as a personal choice), garden uses, indoor use for toilet flushing, laundry uses, and/or supply to hot water systems (indoor uses generally require pumped a supply). Industry uses are variable but potentially may include use for fire fighting, use in building cooling systems, and various commercial uses including use in food production (e.g. market gardens) and plant nurseries	Water quality risks include: microbiological (e.g. contamination of the roof catchment by birds and other animals). Though can be managed through minimal interventions Industrial fallout in some areas Potential for mosquito /pest breeding sites resulting from poorly maintained roof/tank catchment systems Though can be managed through minimal interventions Volume related risks include: highly variable supply supply being dependent on level of use not likely to be the sole source of supply in urban settings due to space limitations unless underground tanks are established	Reduced dependence on mains water and potential for providing water during periods when mains water may be unavailable (e.g. during periods of mains breakage/repair & maintenance) Reduced volumes of runoff may potentially contribute to the effectiveness of 'off-site' stormwater management and/or help to reduce the size/cost of off-site systems such as wetlands. However such benefits if any would be site/catchment specific May be potential, through temporary detention storage to mitigate stormwater flows during minor stormwater events

Short definition	Treatment undertaken	Use post treatment (at present, and potential in the future)	Potential hazards and associated risks	Side benefits
Demand management				
A change in water use with the aim of reducing the overall demand for water. Demand management is separated into: water conservation (any action that reduces the volume of water used. Water conservation may impact on the water user's amenity or level of service, e.g. restrictions) water efficiency (any measure that reduces the amount of water used per unit of a given activity, without compromising the achievement of the value expected from that activity e.g. installation of water efficient appliances).	Not Applicable	Generally targeted at drinking water supply but can cover all types of water demand. Education, incentives (e.g. rebates for water conserving measures), various policy measures (e.g. restricted watering times, or other forms of restrictions), water-efficiency information/requirements (e.g. the national Water Efficiency Labelling and Standards Scheme) and pricing regimes, may lead to modified end user demand	Reduction may not be long term, depending on measures taken Severe reduction in water use may have potential to impact on sewerage systems (e.g. increased incidents of on-site or off-site sewer blockages) Some measures (e.g. water restrictions) can impact on society and the urban environment	Potential for increased awareness of the 'value' of water resources Some measures (e.g. the national Water Efficiency Labelling and Standards Scheme) have stimulated business innovation

B.2 Further terms

Term	Short description	Source
Catchment	An area of land surrounding a water storage. The runoff water from rain falling over the catchment drains into the storage and collects nutrients, minerals and other contaminants (including microorganisms) from the surface of the land	[1]
Desalination	A water treatment process used to convert highly saline water into water suitable for human consumption. Treatment involves passing saline water through membranes at a high pressure	[1]
Desalination water	The volume of water sourced from desalination processes and is not confined to marine desalination	[2]
Drinking water	Water that is suitable for human consumption	[1]
Greywater	Water that is discharged from household appliances (such as washing machines and dishwashers) and from sinks, showers and bathtubs. It does not include water discharged from toilets—this is called 'black water'	[3]
Groundwater	Water beneath the earth's surface (often between saturated soil and rock) that supplies bores, wells or springs	[1]
Inflows	Water flowing from catchments into reservoirs through streams, rivers and creeks	[1]
Non-drinking water	Water that is not suitable for human consumption	[1]
Non-potable water	Water that is not intended for use as a drinking water supply	[2]
Potable water	Water that is intended for use as a drinking water supply. Potable water should materially meet the Australian Drinking Water Guidelines 2011 (ADWG) or equivalent	[2]
Raw water	Water that is untreated water	[2]
Recycled water	Treated sewage effluent, including sewer mining and it may be potable or non-potable. It excludes any urban stormwater use	[2]
Reservoir	A natural or artificial body of water used as a storage for water supply	[1]
Source water	Water prior to any treatment or disinfection	[1]
Treatment (water)	The filtration and disinfection processes employed to produce drinking water	[1]
Urban stormwater	Water within the urban stormwater drainage system. Urban stormwater may be received from or supplied to other infrastructure operators). It may also be supplied for managed aquifer recharge	[2]
Urban stormwater	Treated urban stormwater used by the utility for urban water supply and it may be potable or non-potable	[2]
Water supply system	The complete system that provides a water supply to customers. It includes all infrastructure from catchment to tap, including the source water, water storage reservoirs, treatment plants and distribution networks	[1]

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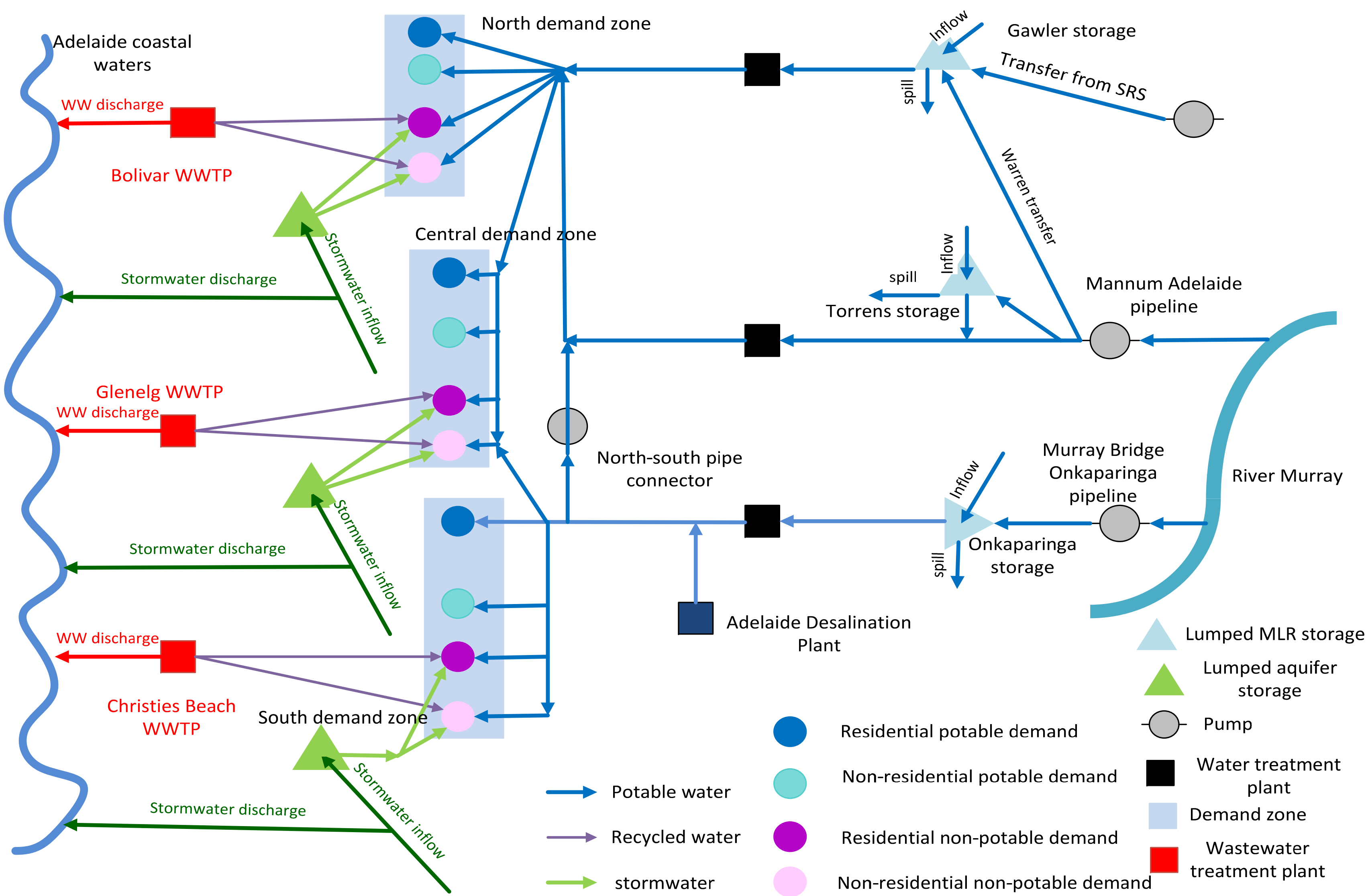
Appendix C Metro Adelaide urban water supply model schematic



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