Methods Used to Develop an End Use Model & Demand Management Program for an Arid Zone

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Abstract Outdoor demand in arid climates generally represents a significant proportion of total demand and is often extremely seasonal in nature and difficult to characterise, leading to problems when building an end use model and determining which options will provide the highest water savings at the lowest cost. In the investigations undertaken for Alice Springs, a wide variety of low cost methods for gathering data were used to disaggregate water demand, build an end use model and assist in the development of the demand management (DM) program. These included: analysis of bulk water and customer metered demand; review of available data and documents on water issues; the use of a low cost residential water usage survey which was linked to customer metered demand; interviews with suppliers/maintenance specialists (e.g. pools, air conditioners and garden irrigation); and an experiment in relation to evaporative air conditioning systems. During these investigations it was found that the unit cost of the individual DM options ranged from as low as 0.20 AUD per kilolitre for some institutional efficiency options to 1.40 AUD per kilolitre for residential washing machine rebates. It was also found that due to the high energy costs associated with pumping water from the existing supply, considerable savings could be made by deferring borefield augmentation and operating costs. In fact for the proposed demand management program, combining 15 individual DM options, the savings in operating costs for water supply alone exceed the whole of society costs of the DM program. This paper will be useful to those dealing with water efficiency issues in arid zones by providing details on cost effective data/information sources and methods, the use of climate correction, the types of DM options available for arid zones and details of typical unit costs.

Keywords arid; Australia; end use models; data gathering methods; demand management programs; water efficiency.

Introduction

Alice Springs is a town with a population of approximately 27,000 people, located in the arid centre of Australia, in the Northern Territory. Two Northern Territory Government bodies, the Department of Infrastructure Planning and Environment (DIPE) and the local water utility, Power and Water Corporation (PW) have recognised the need to use a coordinated approach to managing water resources in Alice Springs. Hence they established the Alice Springs Urban Water Management Strategy (ASUWMS), which aims to use a combination of approaches including demand management (DM), alternative sources and effluent reuse to reduce potable water demand and wastewater production in Alice Springs.

The Alice Springs Water Efficiency Study (the Study), which is the subject of this paper, looks specifically at DM opportunities and thus forms a part of the ASUWMS. The aim of this Study was to identify options for reducing both water demand and the production of wastewater effluent in Alice Springs principally in order to:

- reduce the need for augmentation of the major groundwater supply, the Roe Creek Borefield;
- reduce the need for augmentation of the reticulation system because of future population growth; and
- reduce the volume of effluent overflow from the wastewater treatment plant (WWTP) passing to Ilparpa swamp, adjacent to the town and therefore to subsequently reduce mosquito breeding and other public health threats.

Potable water demand in Alice Springs, in a business as usual scenario, is expected to rise from the current 10,000 megalitres per annum (ML/a) to approximately 12,500 ML/a by 2021 due to the projected rise in population. The Study developed two DM program scenarios, which could reduce water demand by at least 1,050 ML/a and 3,400 ML/a by 2021 at an estimated cost of 3.8M AUD and 10.2M AUD respectively. The costs of implementing either of these program scenarios would be recouped by the energy savings obtained from reduced water pumping requirements alone. In addition to reducing the demand for potable water both programs would: reduce wastewater production with subsequent environmental and social benefits in relation to Ilparpa swamp overflows; reduce and/or defer capital investment required to augment the potable water and wastewater systems; reduce greenhouse gas emissions (GHG); and provide significant additional social and environmental benefits.

The Demand for Water

The population of Alice Springs is expected to grow by more than 5,500 people in the next 20 years from 27,000 (2001) to 32,500 (2021) which represents an increase of 20%. Without investment in DM, source substitution or reuse alternatives, per capita demand for potable water is likely to remain at or near current levels. Hence the demand for potable water in Alice Springs is likely to increase in the future, from the historical average over the last 10 years of approximately 10,000 ML/a to around 12,500 ML/a by 2021.

Figure 1 shows the historical and projected: customer metered demand; metered demand including source substitution (non potable supply from the Town Basin); and the total water supplied by PW which includes unaccounted for water (UFW), metered potable water and metered source substitution. This water demand projection represents the reference case demand or business as usual case and has been used to assess the effectiveness of DM options in achieving identified demand reduction targets. The reference case incorporates anticipated improvements in water use efficiency, which will occur without PW intervention (e.g. stock turnover of 12 L single flush toilets with water efficient 6/3 L dual flush toilets).

Figure 1 indicates that there has been a downward trend in total water supplied over the last ten years. However, based on detailed analysis of the data, the recent reduction in demand can be attributed to two main factors:

- a gradual reduction in system losses or UFW from 21% to 12%, except for 2001 when a major leak contributed to UFW increasing to 27%; and

- a reduction in customer metered demand in 2000 and 2001 due to above average rainfall, which significantly reduced demand in both the residential and non residential sectors.

The per capita metered demand has remained fairly constant and is expected to remain so unless a demand management program is implemented. Hence overall water demand is expected to increase, as the population grows, as shown in the projection in Figure 1.

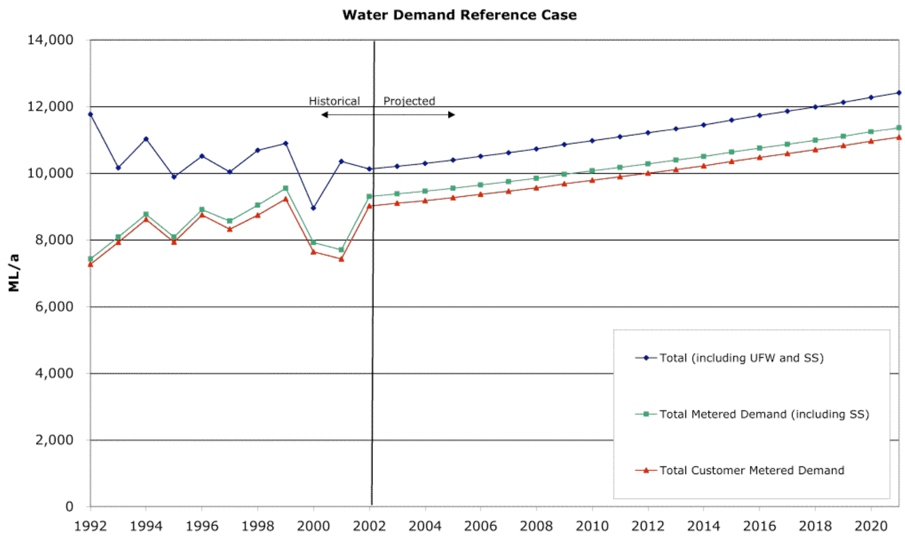

Figure 1 Water demand reference or business as usual case (ML/a). Note – SS represents the Town Basin source substitution (from a superficial aquifer in the Todd River Basin) and UFW represents unaccounted for water.

Water Supply Constraints

The implications of this increase in water demand are that aquifer levels will continue to fall, as the current annual extraction exceeds the recharge rate of the primary potable water supply aquifer. The water level of this aquifer is currently at more than 145 m below ground level and is falling at a rate of between 1 to 2 m per year with the current level of water demand. This means that additional capital expenditure will be required to drill new bores or rehabilitate existing bores just to reach the lowering aquifer levels to meet current demand. With greater demand from the additional population the aquifer level will drop more quickly resulting in additional capital costs being required for new bores and to deepen existing bores and earlier in terms of capital expenditure planning. In addition as the aquifer levels fall energy costs associated with pumping will increase as water is extracted from greater depths. Even with no increase in annual demand, extraction depths will increase from the current 145 m to around 190 m by 2021. If demand increases to around 12,500 ML/a, as projected by this Study (the reference case), the extraction depths of the bores could potentially increase to an estimated 240 m by 2021.

The energy consumption and costs associated with extracting and pumping water in Alice Springs, currently approximately 1,100 kWh/ML and 150 AUD/ML respectively, are amongst the highest in the Australian water industry. These will increase as the aquifer level falls further. Hence, if water demand is reduced, significant benefits can be obtained such as avoided or deferred capital and operating costs for water supply and wastewater treatment and disposal, reduced capital and operating costs for the electricity supply system and reduced GHG emissions.

Sewage Overflows

The average annual volume of wastewater passing to the WWTP is currently estimated to be between 2,500 and 3,000 ML/a. This is expected to rise as the population grows. The existing WWTP is nearing both hydraulic and treatment capacity and wastewater effluent overflows from the WWTP (estimated to be approximately 600 ML/a) currently discharge to Ilparpa swamp causing ecological and mosquito breeding problems. These overflows are generally at their peak during winter months when evaporation rates are at their lowest and visitor numbers are at their highest. It is expected that these issues will continue as the population grows unless significant intervention is adopted (e.g. DM or effluent reuse).

An investment of up to 10M AUD for storage and effluent reuse is planned by PW over the next five years to reduce overflows by establishing an effluent transmission system to supply a horticultural district on the outskirts of Alice Springs. A DM program that targets indoor water demand and the tourist sector will provide not only water demand reduction but also a reduction in terms of wastewater production, thus reducing the flows passing to the WWTP and overflows to Ilparpa swamp. Hence a DM program could assist in reducing the capital expenditure required for the planned reuse scheme, reduce or defer the capital costs associated with the future planned WWTP hydraulic and treatment upgrade and general operational costs associated with the wastewater system.

The Study Approach

The first stage of the Study was to use a wide variety of low cost methods for gathering data in order to disaggregate water demand, build an end use model and assist in the development of the DM program. These included: analysis of bulk water and customer metered demand; review of available data and documents on water issues; the use of a low cost residential water usage survey which was linked to customer metered demand; interviews with suppliers/maintenance specialists (e.g. pools, air conditioners and garden irrigation); and an experiment in relation to evaporative air conditioning systems.

This data was gathered for individual end uses and sectors, verified using various sources where possible and used to build the end use model. For example, in the outdoor residential sector the number of evaporative air conditioners, how often they are used and their average water consumption together with the current population, housing stock and occupancy ratio were used to identify the proportion of total water used by evaporative air conditioners per capita per day and per household per annum. Then using the projected demographics data the water demand per person and per household for air conditioning was projected to 2021. The techniques used to develop the end use model for the Study and typical per capita and per household demand are detailed in a separate paper (Turner et al, 2003a).

The main outputs from the end use model are the water and wastewater reference cases against which the options developed are to be tested. Both the water and wastewater historical reference cases have been calibrated against the bulk water supply, customer metered demand and wastewater output records to further verify the accuracy of assumptions and the model developed.

As the seasonal variation in demand for water is so significant in Alice Springs, a climate correction model was also developed which identifies the impact of climate related variables (e.g. rainfall, evaporation and temperature) on bulk water supply. Using these variables and by correcting for population increase over the last 20 years, a predicted bulk water supply demand curve has been developed for Alice Springs (Turner, et al 2003a).

The main aim of the Study was to develop a suite of options (the DM program), which together reduce annual and peak potable water demand as well as wastewater production. The DM options were developed using the principles of least cost planning (LCP) where LCP involves the development and analysis of a range of options to determine the least cost means in terms of whole of society costs (AUD/ML supplied or saved) of providing customers with the water related services they require (White 1998, White and Howe 1998). This process recognises that customers do not necessarily want more water, rather they want the services that water provides (e.g. aesthetically pleasing landscapes, sanitation and clean clothes) and that every litre of water saved is the equivalent of a litre supplied. The DM options developed during the Study target a broad range of customers in all sectors (e.g. residential, commercial/industrial and institutional) and individual end uses such as indoor (e.g. toilets, taps, showers) and outdoor (e.g. pools, air conditioners, gardens). They also use a wide range of approaches to increase indoor and outdoor water efficiency including the use of a measure (e.g. increased water efficiency through the fitting of a AAA-rated showerhead) and an instrument (e.g. an economic incentive whereby PW pays for the showerhead and labour and a communication strategy where PW provides a brochure on water efficient tips around the home).

The Options

The options that were developed during the Study, have been grouped as follows together with their present value whole of society levelised costs (AUD/kL), (Turner et al, 2003b):

- residential indoor – residential indoor retrofit (0.53), washing machine rebate (1.39), public/government housing retrofit (0.27);
- residential outdoor – residential outdoor water efficiency visit (0.26), targeted outdoor visit (0.05), pool cover rebate (0.63), air conditioning program (0.51);
- other residential – targeted residential program (0.28), aboriginal communities program (0.14);
- commercial/industrial – general auditing (0.53), hotels program (0.19);
- institutional – general program (0.38), hospital program (0.56), schools program (0.18);
- new developments – residential (0.30) and non residential (0.55) building controls; and
- other options such as leakage.

The options included a combination of measures and instruments such as: retrofitting appliances and fittings (e.g. toilets, showerheads and taps); specialist visits to targeted properties to investigate outdoor water use; provision of give-aways such as tap timers; rebates for the purchase of AAAA-rated washing machines; audits and associated retrofitting and management advice for hotels; and development controls for new residential and commercial buildings. Targeting of new developments was included to ensure that water efficiency is locked in to new residential and non residential developments as far as possible. This is in order to reduce future investment in DM measures and to take advantage of the fact that generally the inclusion of water and energy efficiency in new buildings has only a marginal impact on the overall cost of the building. In addition, such buildings can relatively easily incorporate options such as DM, source substitution and reuse.

Savings in terms of total water, peak day water, sewage effluent, energy and GHG were modelled together with total implementation costs for each option based on assumptions around take-up rates and savings levels.

These options were developed into three water saving scenarios (1 – low, 2 – medium and 3 – high) to determine the level of investment required to achieve the ASUWMS Reference Group preliminary goals of:

- a 25% reduction in total annual water demand over the first three years, with a further 10% reduction in the following two years;
- a 10% reduction in peak day demand over the first three years, with a further 5% reduction in the following two years; and
- a reduction in inflows to the WWTP from 8 ML/d to 7 ML/d.

Each of the scenarios uses the options developed with varying levels of implementation. Scenario 1, with the lowest costs, shows the baseline savings achievable and represents a standard efficiency options program. In this scenario the participants in a retrofit program might be assumed to be 50% of all available households. Scenario 2, the mid-range scenario, has involved consideration of which of the model's assumptions may reasonably be increased (for example take-up rates) and at what cost. In this scenario the participants in a retrofit program might be assumed to be considerably more at 75% of all available households, which could potentially require additional incentives and thus cost more to attract the level of participants needed. By changing the take-up rate of those options with the lowest cost first (AUD/kL), it has been possible to develop Scenario 2 at the lowest cost. The high scenario (Scenario 3) was not developed, as it was considered that Scenario 2 pushed the DM options assessed to the limit of their application (in terms of their uptake) and that a more holistic approach combining DM, leakage control, source substitution and reuse would provide the overall savings required at a lower average unit cost.

Table 1 shows the results of this process and the scenarios compared with the reference case. Figure 2 shows the targets and anticipated savings of Scenarios 1 and 2.

Scenario	Resulting Demand (ML/a in 2008)	Demand Reduction estimated (ML/a in 2008)	Resulting Demand (ML/a in 2021)	Demand Reduction estimated (ML/a in 2021)	Total cost – present value (AUDM)
Reference case	10,715	N/A	12,405	N/A	N/A
1	9,714	1,001	11,339	1,066	3.8
2	8,020	2,695	8,979	3,426	10.2

Table 1 Demand Management Program Scenarios

The DM programs developed as Scenarios 1 and 2 are estimated to cost approximately 3.8M AUD and 10.2M AUD respectively in whole of society present value terms (using a discount rate of 7%). Whilst neither of these scenarios actually meet the preliminary ASUWMS Reference Group targets, it is important to recognise that neither of the scenarios incorporate the full range of opportunities available for inclusion of options relating to leakage control, source substitution or reuse. In Scenario 1, options related to new developments have assumed the use of source substitution/reuse to a limited extent. In Scenario 2, such options have assumed a higher level of source substitution/reuse in addition to specific targeted options, to attain low potable water demand per household.

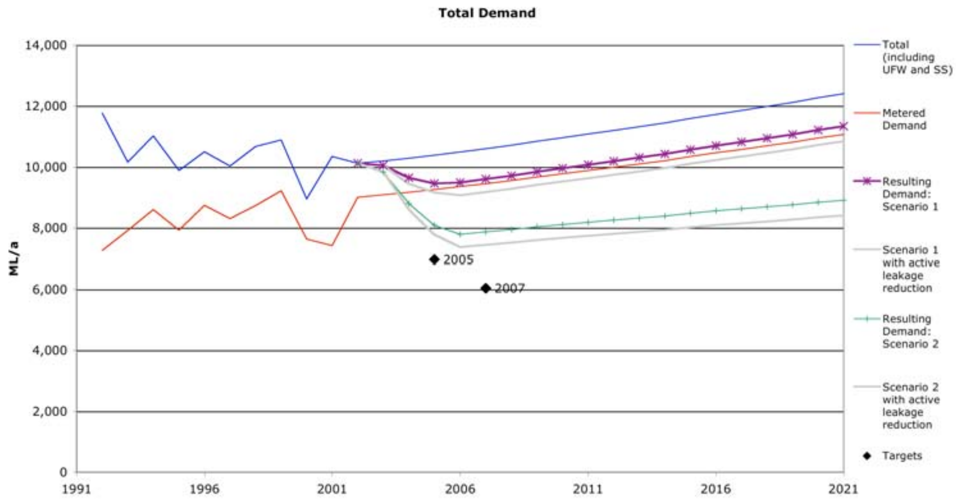

Figure 2 – Demand management targets and water savings for scenarios 1 and 2 (ML/a)

Although not part of the brief for this Study, Figure 2 also provides an indication of how leakage reduction in the PW maintained system could assist in reducing overall demand. The leakage reduction identified is an estimate and indicates the savings available if PW leakage was brought in line with other Australian water service providers at the lower end of current Australian leakage practice. Further leakage reduction could potentially be achieved if PW leakage was brought in line with current international best practice. The estimated savings and costs identified in Table 1 for Scenarios 1 and 2 do not include these potential leakage savings or costs as these will be further investigated by PW.

As indicated, Scenario 3 has not been developed as it is considered that Scenario 2 pushes the DM options developed to the limits (in terms of uptake). It is recommended that a more holistic strategy is developed for Alice Springs including the DM options developed as well as leakage, source substitution and reuse options. Some of these options have already been developed to an extent as part of the ASUWMS previous work, however, assessment of all these options together using an LCP approach has not been carried out to date. The evaluation of all options (the reference case, DM, leakage reduction, source substitution and reuse) should be reviewed using an LCP approach and using the same population and per capita demand assumptions (developed as part of this Study using a detailed end use analysis approach). This will enable PW/DIPE to determine the least cost strategy to take forward for implementation and to ensure that all cross benefits are identified and evaluated. In addition the targets should be reviewed by the ASUWMS Reference Group in the light of the findings of this Study and further assessment of alternative options, such as leakage and source substitution, should be evaluated considering the level of investment required to achieve the preliminary DM targets.

As a minimum the Study findings indicate that PW should invest in the baseline savings DM scenario (Scenario 1) at 3.8M AUD. Water efficiency through a DM program is essential for other options (e.g. supply from additional bores, source substitution and reuse) to provide services effectively and to reduce their unit cost (AUD/ML) in terms of meeting required demand. For example, if the existing potable water supplied is used more efficiently through DM then more customers can be supplied with the water saved at no extra cost. In addition, if water required for the watering of ovals from the non potable Town Basin supplies is used more efficiently then the water saved can be used for other customers such as hotels for outdoor water use at no extra cost and reduces the demand for potable water demand by these customers. Hence a DM program is effectively a foundation upon which to build alternative supply options. Without a DM program investment in alternative options will not be optimised as the water being provided will still be wasted.

Investment in Demand Management

As previously identified Scenarios 1 and 2 are estimated to cost 3.8M AUD and 10.2M AUD respectively. These are the full costs of each program and assume that PW will (in a similar way to investment in borehole augmentation) pay for all required costs (whole of society), thus, maximising the potential take-up rates by participants of the options and incentives developed.

As mentioned previously this investment will effectively be recouped in the form of deferred or avoided capital and operating costs in the water and wastewater (and potentially energy) infrastructure. Table 2 shows the capital and operating expenditure and savings for potable water for the reference case and Scenarios 1 and 2.

Scenario	Reference Case Borehole Expenditure Present Value A$M	Scenario 1 Borehole Expenditure Present Value A$M	Scenario 1 Borehole Expenditure Savings Present Value A$M	Scenario 2 Borehole Expenditure Present Value A$M	Scenario 2 Borehole Expenditure Savings Present Value A$M
Water					
- capital	5.1	4.7	Savings proportion unknown	3.9	Savings proportion unknown
- operating	23.7	20	3.8	14.1	9.7

Table 2 Capital & Operating Water Expenditure & Savings

The table shows that the present value savings in operating costs for Scenarios 1 and 2 are 3.8M AUD and 9.7M AUD respectively. This indicates that for Scenario 1 the present value savings in operating costs for water alone actually pay for the Scenario 1 DM program (3.8M AUD) and there is only a 0.5M AUD shortfall for Scenario 2 (10.2M AUD). Hence if the savings attributable to deferred capital expenditure for the water system and deferred capital and operating expenditure for the wastewater and electricity system were also included, the DM costs for both scenarios could easily be paid for.

References

Turner, A. Campbell, S. & White, S. (2003a) 'End Use Modelling & Water Efficiency Programs for Arid Zones: The Alice Springs Experience' Efficient 2003: Efficient Use and Management of Water for Urban Supply Conference, Tenerife, 2-4 April 2003.

Turner, A. Campbell, S. & White, S. (2003b) 'Alice Springs Water Efficiency Study Stages I & II - Final Report - Volume I', Report prepared by the Institute for Sustainable Futures for PW/DIPE

White, S. 1998 Wise Water Management: A Demand Management Manual For Water Utilities, Water Services Association of Australia Research Report #86, WSAA, Sydney.

White, S. and Howe, C. 1998, 'Water Efficiency and Reuse: a least cost planning approach', Proceedings of the 6th NSW Recycled Water Seminar, November.