MANAGING DROUGHT: LEARNING FROM AUSTRALIA

Alliance for Water Efficiency
Institute for Sustainable Futures, University of Technology Sydney
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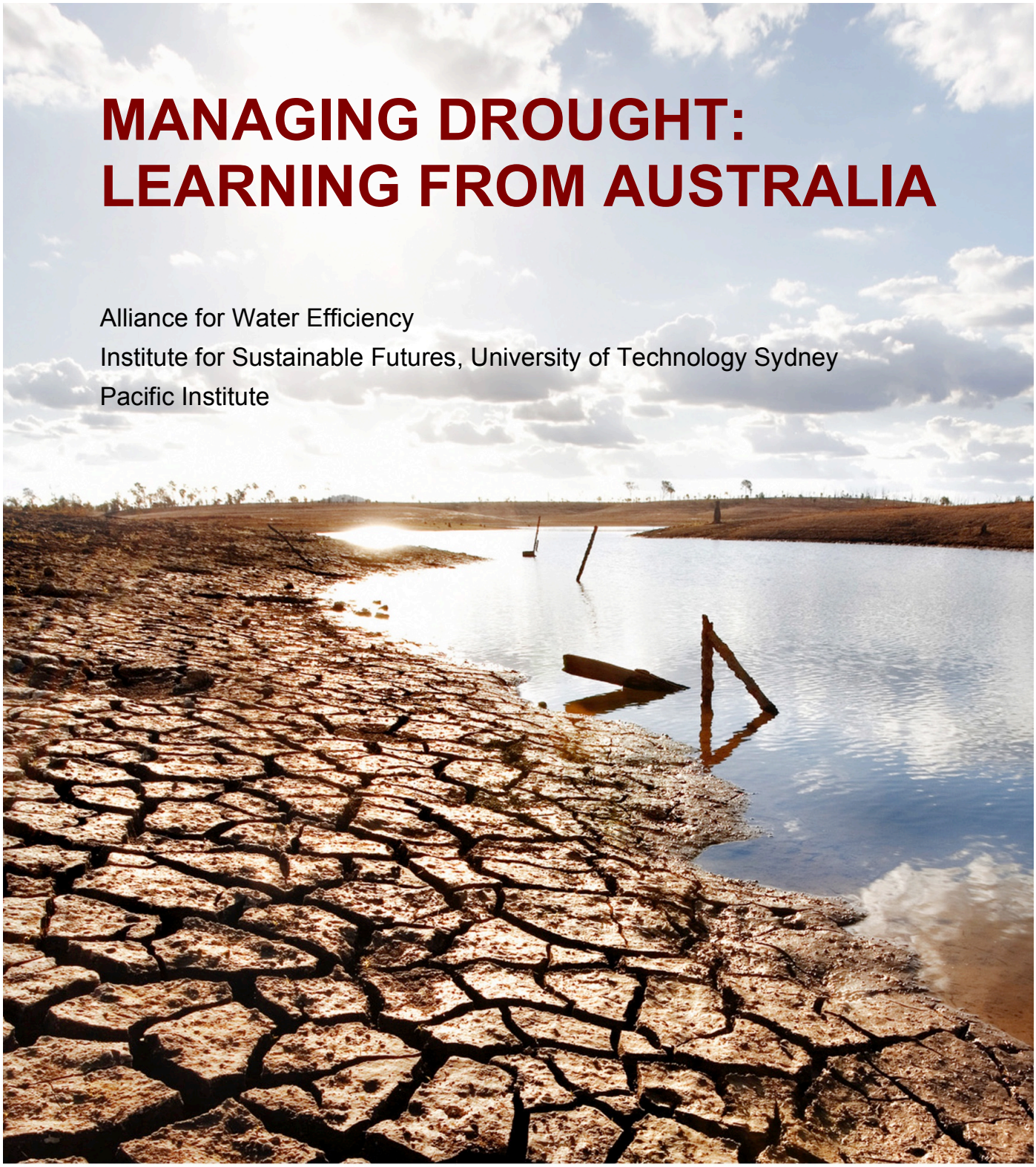

ABOUT THE AUTHORS

The Alliance for Water Efficiency is a stakeholder-based non-profit organization dedicated to the efficient and sustainable use of water. Headquartered in Chicago, the Alliance serves as a North American advocate for water efficient products and programs, and provides information and assistance on water conservation efforts.

For further information visit: www.allianceforwaterefficiency.org/

The Institute for Sustainable Futures was established by the University of Technology Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human wellbeing and social equity.

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EXECUTIVE SUMMARY

California is facing yet another year of unprecedented, record-breaking drought. At this time of need, US agencies have turned to Australia to identify the strategies that urban water utilities and water agencies adopted to survive its worst drought in recorded history, the Millennium Drought, which lasted from 1997 until it officially ended in 2012.

Overall, Australia survived the Millennium Drought, demonstrating world leading innovation and exceptional examples of water planning and management driven by crisis. Yet there are also examples of missed opportunities, as well as initiatives and decisions that did not work well. The research presented here reflects on some of the key lessons from the Australian Millennium Drought experience in order to assess the opportunities for California.

This report serves as a powerful resource for Californian water planners and managers as it grapples with drought and seeks to build resilient and sustainable water systems. It provides a one-stop shop overview of the key events and initiatives implemented in Australia's four largest cities – Sydney, Melbourne, Brisbane (and the surrounding south east Queensland region), and Perth.

The work represents one interpretation of the drought and responses, informed by significant engagement with utilities and governments throughout that period, and a close working knowledge of the water systems and the policy environment.

Specific attention is given to the role of demand-side measures in reducing the impact of drought. In Australia, urban water efficiency was the quiet achiever – saving more water at lower cost and greater speed than supply options. California can benefit from long-term structural water savings by implementing water efficiency measures at a similar breadth and scale.

On top of the success of urban water efficiency, this report highlights a number of key findings from Australia's experience of the Millennium Drought.

- **Responding to a severe drought requires *both* supply-side and demand-side options. It is crucial to implement the cost-effective *(lowest cost per volume)* options first**. Although an individual demand-side program may save less water in total than could be supplied by a large-scale infrastructure augmentation, this does not by itself justify prioritizing all supply options – depending on the context, some large-scale supply infrastructure can be overall more costly, and have longer lead times for implementation. During the Australian Millennium Drought, a broad range of cost-effective water efficiency programs, rapidly rolled out at scale, saved significant volumes of water and reduced the rate of drawdown of dams.

- **Powerful demand-side programs encourage and support water savings from across the breadth of water users and stakeholders – households, businesses, industries and governments.** This maximizes the potential for water savings and can achieve economies of scale, particularly for household programs that target multiple uses and residents. Equally important, across-the-board community involvement of all sectors fosters a sense of fairness and collaboration in saving water, and acceptance and support for overall drought response strategies including restrictions and targets.

- **An effective supply-side strategy considers modular, scalable, diverse and innovative technology options.** As the duration and severity of a drought at any point is unknown, a rapid yet progressive approach to the supply infrastructure and contract decisions is required to avoid technology and vendor lock-in, and to prevent costly post-drought stranded assets. Also, drought presents the need and opportunity to invest in innovative supply and reuse options at scale, to test and develop approaches to implementation, policy and public acceptance.

- **Clear, credible communication about the drought situation and response is paramount to public participation and support**. In the Australian Millennium Drought, multi-modal approaches to promotion, education and communication spanned information about water savings, water storage levels, requirements and expectations about drought, and planned supply options. Drawing on their experiences during the drought, some cities have also developed "forward-looking" outlook scenarios with clear outlines of response plans in different drought situations.

- **Good data and robust monitoring and evaluation are critical.** To manage demand requires measurement at the sector, household and end use levels in order to be able to design and implement well targeted water saving measures. Similarly, accurate measurement and analysis of the sustainable yield of supply systems is an integral part of supply–demand planning and drought response. Measurement of the savings from water saving programs is also critical to improving the design of future programs.

- **Innovative water pricing mechanisms are required to balance water savings, revenue and equity goals.** During the Millennium Drought, pricing was not used to incentivize water savings. However, following the drought in several jurisdictions prices rose significantly, more in response to infrastructure expenditure than to cover revenue shortfall from reduced demand. There is potential to explore more innovative, revenue-neutral pricing mechanisms such as "fee-bate" schemes which reward low water users and penalize higher water users.

➔Lessons from Australia

The impact of the Australian Millennium Drought on urban water supplies varied widely across the country due to differing climates, water supply systems and policy responses. Different stakeholders also experienced the drought in different ways. This summary, and the background material on which it is based, represent one interpretation of the drought and responses to it. It is an interpretation that is informed by significant engagement with utilities and governments throughout that period, and a close working knowledge of the relevant water systems and policy environments.

This summary uses five key dimensions to represent five ways of thinking about the lessons that might prove useful in California. These dimensions were identified by considering and documenting the Australian and Californian droughts. We analyzed: four Australian case studies, a number of initiatives that were implemented during the Millennium Drought, and other initiatives that helped to mitigate its impacts.

1. MANAGING CRISIS AND OPPORTUNITY

The drought presented as both a crisis and an opportunity to innovate – to roll out new water savings initiatives and incentives at scale, and to leverage community and political will to make needed policy and regulatory changes. At the same time, politicized, crisis-driven decision-making resulted in costly over-investment.

Australia is prone to droughts, but the Millennium Drought was different. In some cities it was the worst on record. The falling dam levels raised concerns within the water industry that Australia was facing the impact of a shift in inflows due to climate change and brought about a realization that water usage in Australia was too high, and that the country was too vulnerable due to its reliance on rain-dependent water sources. These concerns highlighted the need to diversify water sources by adopting measures spanning water efficiency, source substitution, major reuse, and non-rain-dependent supplies, such as desalination.

The gradual realization of the severity of the drought and Australia's vulnerability sparked a series of responses that included world-leading innovations, and both very good and poor examples of water planning and management. The heightened concern about climate change increased the political will for action and hence the funding available for drought response measures, as well as the potential for shifts in policy and water use.

> Significant investments were made right across the board in initiatives ranging from water efficiency and source substitution such as rainwater tanks through to major recycling and supply options such as desalination.

Due to major investments in water efficiency programs and restrictions on outdoor water use, water demand dropped significantly. Further water savings were achieved through building regulations requiring water-using equipment in new and refurbished homes. In some cities, large structural and behavioral shifts in water demand were achieved through suites of water conservation initiatives. For example, in South East Queensland residential water demand fell by 60% to 33 gpcd (125 lcd) and has only increased to around 45 gpcd (170 lcd) since then. These savings helped to delay or eliminate the need for expensive, new water and wastewater infrastructure to accommodate future population and economic growth.

New policy measures were also developed. For the first time, governments contemplated real options planning, based on the principle of readiness – for example, by being 'ready to construct' Sydney's desalination plant as insurance should dam levels drop below a specified trigger level. This planning approach allows greater flexibility for investment in large capital items by making the expenditure 'staged' and modular. It also allows for the option to curtail completion of a plant if conditions change.

Responses to the Millennium Drought also provide cautionary lessons. In particular, careful planning by government agencies and utilities in several instances was set aside by political decisions. This occurred in the Victorian Government's decision to construct a desalination plant and implement inter-catchment transfers, in the NSW Government's decision to construct the desalination plant regardless of dam levels, and in the Queensland Government's decision to construct the Traveston Dam – a decision that was subsequently overturned. These examples highlight a significant risk of crisis-driven decision-making when future rainfall patterns are uncertain – this can result in over-investment in large-scale infrastructure that is expensive, energy-intensive, subject to unfavorable contractual terms, and in many cases not actually used, resulting in costly stranded assets that will need to be paid for by the community for decades, well ahead of when they may be needed.

2. WORKING TOGETHER

Strong partnerships, knowledge sharing and coordination between organizations – states, agencies, utilities, researchers and industries – supported success during the Millennium Drought. After the drought these collaborations can dissolve, and governments and utilities face the challenge of retaining the savings and knowledge that these partnerships have made possible.

First, dedicated investment in partnerships between government agencies, utilities, industries, and communities were fundamental to designing and implementing successful water savings programs. These programs involved governments and utilities partnering with businesses that used water, with businesses that manufactured and supplied water-using devices, and with businesses that provided services to help customers manage their gardens.

> These partnerships stimulated a multi-million dollar water efficiency industry during the drought years.

These partnerships also helped to signal a “we’re all in it together” approach to water efficiency, and they helped generate public support for overall water management initiatives. In Western Australia, there was a long history of the Water Corporation and the state government engaging businesses in programs to build capacity and provide accreditation to practitioners, especially in the irrigation and landscaping industries. Across Australia, ‘green plumber’ programs were supported to encourage tradespeople to become involved in the task of improving water efficiency. Water efficiency programs were funded and their implementation facilitated by utilities and state governments – with many industry associations and trade groups (such as plumbers’ associations) dedicating their in-kind time.

Second, government agencies formed drought response teams across departments and utilities, often at a high level, to address the drought. In the state of New South Wales for example, the ‘Water CEOs’ group’, comprizing the heads of all water-related agencies and water utility CEOs, was convened and tasked with managing the drought response, with the head of the Cabinet Office as chair. Whilst some coordinating groups met during the drought only, in some areas such as in Melbourne, the Drought Coordinating Committee members have since reconvened to review and revise the approach to drought planning and response.

Third, sharing information and experiences across the industry – between utilities in each state and between state government agencies – also helped to drive success. For example, in Perth and Melbourne, detailed surveys and analyses of how people use water were shared among utilities, spawning a new era of detailed sector and end use-based forecasting of water demand and potential savings. And in South East Queensland, where the timeline for implementation of water efficiency programs was extremely short, advice from Sydney Water proved invaluable. Sydney Water had implemented similar large-scale programs prior to the drought, and had subsequently evaluated them to demonstrate savings. Water companies and state governments were instrumental in commissioning and supporting applied, water-related research across all domains (including climate variability, seasonal forecasts, pricing, conservation/efficiency programs, institutional analysis, systems modeling, and environmental water needs) and in documenting and sharing knowledge at industry events and conferences.

The Millennium Drought stimulated significant applied research worth millions of dollars that was shared through multiple channels, including industry conferences and/or utility interest groups (e.g. the Water Services Association of Australia and the Australian Water Association). Whilst some locations have seen a shift since the drought towards discussions about the importance of water in urban landscapes for “liveability” and the role of water efficiency in integrated water management, in general after the drought investment in water efficiency and water efficiency teams waned. As a result, the new water efficiency industry partnerships and research dissipated. This has created two challenges: how to maintain water savings that were partially dependent on ongoing partnerships, and how to retain such knowledge for future droughts.

3. SPEAKING AND LISTENING

Communication and public engagement on water savings programs and the water scarcity situation were essential to the success of all water saving initiatives. However, in many places, governments and water utilities failed to grasp the opportunity to undertake best practice community engagement and water-supply decision-making.

Many water efficiency marketing and media campaigns were extremely effective in fostering community support and action. Utilities and governments applied a variety of interlinked communication approaches and targeted a wide range of stakeholders. For example:

- Linking the restrictions message with the availability of incentives, rebates, and other water savings initiatives was a very effective mechanism for lessening the potential for negative responses.
- There were concerted efforts to implement restrictions on outdoor water use as a key pillar of a public promotion and education campaign across users and sectors, to help foster the sense that all types of water users were obliged to help save water. As a result, communities were generally supportive of restriction programs during the drought.
- In some regions, the media was extensively used, for example to provide information on dam levels and per capita water consumption in evening news broadcasts. Engaging the media was a crucial element in the effectiveness of campaigns to reduce water use.
- The 'Target 140' campaign in SEQ and the 'Target 155' campaign in Victoria applied clear and consistent messaging and helped to focus the campaigns to reduce water use and reinforce community support for a common goal. These, and similar campaigns across the country, exceeded their targets.
- Some initiatives were employed for the first time in Australia, to significant effect. For example, in SEQ the One to One program included direct communication to high residential water users through direct mail with a survey, and links to water saving offers, along with additional follow-up if there was no response.

> Communication and public engagement is a one-to-many activity, with government agencies and utilities speaking to the community.

Successful community engagement means effective listening as well as skilful speaking. Decision-making during drought involves trade-offs – and it is important to invite the community to provide their input on these trade-offs. Despite the sense of urgency to make decisions during a drought, effective citizen engagement does not necessarily involve lengthy processes, and is critical to ensuring decisions reflect community preferences and in turn engendering citizen support. For example, in Western Australia, a robust and comprehensive process of community engagement on water security issues was undertaken in 2003, including a citizens' forum held at Parliament House, addressed by the State Premier. In Melbourne, retail water companies made extensive use of customer consultative committees, and in several locations retailers are required under law to consult with the community on the development of their strategies or operating licences.

However, there were many missed opportunities to implement such best practice citizen engagement processes to maximize the transparency of decision-making and encourage citizens to become involved in and support drought response strategies. In most states, decisions regarding investment, policy choices, water use trade-offs, and levels of service were made centrally, occasionally in consultation with industry representative organisations but not necessarily directly with representative members of the broader community and water customers. Governments did not take advantage of the level of innovation that Australia has demonstrated in deploying robust forms of community engagement. Successful community engagement means effective listening as well as skilful speaking.

4. GETTING THE RULES RIGHT

Governments need to implement best practice policy settings and regulatory arrangements to enable investment in cost-effective supply measures as well as water efficiency measures.

During the Millennium Drought, and since, some Australian utilities have been torn between investing in customer water efficiency programs (which incur operating costs and reduce water demand and revenue) and investing in water supply infrastructure, which involves mainly capital costs. Conventional regulatory settings encourage utilities to minimize operating expenditures and to set prices designed to earn a rate of return on capital. This has the effect of encouraging investment in supply-side options rather than demand-side options, irrespective of the cost-effectiveness of those options.

> It is crucial to have best practice regulations that encourage utilities to invest in customer water efficiency, or better still, regulations which require them to do so.

Sydney Water's regulated operating license required it to achieve aggressive water efficiency targets, and these targets subsequently became a significant component of the Metropolitan Water Plan in 2004, 2006 and 2010. This is an example that shows how regulatory arrangements can strongly encourage investment in demand-side measures. As part of this arrangement Sydney Water publicly reported annually on its performance against the targets for water efficiency, reuse and leakage. These reports are an excellent example of transparency and accountability to the public.

National, regulated schemes providing information about the water efficiency of fittings and appliances were crucial to underpinning rebates, retrofits, audit programs, and building regulation programs. While mandatory labelling and the water efficiency of appliances is, of necessity, regulated by the national government, each state in Australia developed its own regulatory arrangements for water efficiency in buildings, mainly for new houses or major renovations. Some state governments (Queensland, Victoria) opted for more prescriptive regulations, specifying the technologies that were to be installed in new houses, whereas New South Wales developed BASIX, a performance-based instrument requiring new houses to reduce water demand by up to 40% compared to average household consumption in the year of its introduction (2004). There are pros and cons of prescriptive vs. performance-based systems. Poorly chosen rules (such as requiring rainwater tanks in areas with little rain) can involve significant expense for small water savings. On the other hand, robust performance-based systems such as BASIX can be effective but may take several years to develop and implement.

Best practice regulatory arrangements allow for revenue neutrality and for the pass-through of the cost water efficiency measures to the customer. Australia, at the time of the Millennium Drought, had a mixture of regulatory arrangements for utilities, some of which resolved this tension by allowing price pass-through and others that had not. Most utilities continue to face this tension between promoting water conservation and reducing long-term costs for the customer on the one hand, and satisfying regulatory requirements and responding to state government policy drivers on the other. Due to the major expenditure on supply infrastructure during the drought – and the resultant need for revenue to cover the costs – there is a reduced emphasis on utilities and governments implementing water efficiency improvements.

Following the drought, water prices were increased due to expenditure on large-scale infrastructure during the drought – a more significant factor than any revenue shortfall due to reduced water demand. During the drought, in some locations significant attention was paid to frequency of billing to provide pricing and usage information to customers. However, pricing mechanisms, such as fee-bates were not implemented as a water conservation incentive. There were missed opportunities to further investigate whether innovative pricing incentives could be feasibly designed and implemented to achieve water savings during drought while avoiding adverse equity impacts.

5. PICKING THE LOW HANGING FRUIT

During drought, it is essential to consider all supply- and demand-side options, and to prioritize implementing "no regrets" least-cost options. Real options planning, and the concept of "readiness to implement", enable decision-makers to prioritize options and deal with uncertainty about the length and severity of a drought.

An integrated resource planning framework is one that: ensures that all options (supply and demand) are assessed, and compares them on a level playing field; includes risk; and incorporates the full range of costs and benefits. This includes citizen preferences where trade-offs and value judgements are involved. This approach is fundamental to long-term supply–demand planning, which should also encompass drought response planning.

Prior to the Millennium Drought, the principles of integrated resource planning had been recognized in some states, including for example, in the Western Australian Water Conservation Strategy and the Sydney Water Recycling and Water Conservation Strategy. This resulted in plans that incorporated least-cost options, that is, implementing the lowest unit cost measures first, to minimize the overall life cycle cost. In Sydney, for example, the 1995 corporatization of Sydney Water gave rise to an operating license requirement to reduce system per capita demand for total water abstractions from 132 gpcd (503 lcd) in 1991 by 35% to 87 gpcd (329 lcd) by 2011. This was based on the assessment that the previously proposed supply option, a new dam on the Shoalhaven River, had a higher marginal cost than this reduction in demand. Integrated resource planning was used to determine the least-cost strategy to meet these targets.

As a result of this background activity, there was a foundation to build on during the drought. In SEQ, utilities and the state government had been slower to act on pricing reform and direct investment in water efficiency, but when the drought became serious there was major investment in water efficiency options including retrofitting of water efficient equipment, business water efficiency programs, and leakage and pressure management. These had a significantly lower unit cost than almost all the supply options that were implemented.

In terms of drought response options, low cost, 'no regrets' options were pursued, that is implementing measures that would continue to provide a cost-effective benefit after the drought was over. This ranged from accessing deep water storage in Sydney's major dams and the construction of key inter-catchment transfers to increase system yield, through to maximizing investment in reducing system losses and introducing customer-based water efficiency programs.

> Cost-effective water saving measures that had never previously been implemented at scale were rolled out across states and cities. For example, the offer of rebates for water efficient washing machines in Western Australia was so successful that it resulted in a permanent transformation of the industry and the market.

In Sydney, SEQ and Victoria, utilities and governments analyzed the potential for accelerated water efficiency options to 'flatten the depletion curve' of water storages in order to 'buy time' for large-scale supply options to come on line.

In addition, the Millennium Drought saw, for the first time, the application of real options planning, which includes the 'readiness to construct' strategy for desalination or indirect potable reuse capacity or 'readiness to use' groundwater sources. This means staging the planning and implementation of high cost capital works to allow maximum flexibility, depending on water resource constraints and the weather. The real options approach is an example of selecting the lowest-cost option, as it reduces the overall life cycle cost, taking into account the statistical risk associated with rainfall predictions.

Cost-effective investment in water efficiency was done well in many places in Australia prior to and during the drought, and indeed this was the reason that some cities did not reach or come closer to dead storage.

However, the principles of integrated resource planning were not applied consistently. Some cities and towns in Australia had programs of investment in water efficiency that were excellent and very broad, but not deep in terms of the overall level of investment and the extent of the available conservation potential.

➔Measures in summary

During the drought, and leading up to it, there were dozens of measures developed and implemented by utilities, governments and community organizations. This table presents a summary of these measures, with an assessment of the strengths and challenges of each one.

DEMAND-SIDE MEASURES

MEASURE	STRENGTHS	CHALLENGES
Restrictions A core option used during the drought, mainly targeting outdoor water uses in the residential sector, and some non-residential sectors	■ Restrictions, implemented by water utilities in collaboration with state governments, were highly effective at reducing water demand. They were a critical initiative that slowed dam depletion rates and helped to "buy time" for decision-makers. ■ Restrictions were applied at increasing levels of severity as the drought worsened. In some locations, restriction levels were linked to dam levels, which enabled clear communication to and acceptance by the public. ■ Restrictions were widely supported by the public at less stringent levels, and considered as "fair". Key to this was open and effective communication and promotion, and integration within an overall water conservation message (which included other sectors). ■ Most savings gained have remained in place (minimal bounce back) due to a combination of behavioral and structural water efficiency changes. (However due to demand hardening, estimates of savings from restrictions need to be revised for future drought planning). ■ While regulations were in place and some official monitoring occurred, penalties were rarely used. Compliance with restrictions was achieved through engendering community support and monitoring.	■ In some locations, particularly those with drier climates, and where a complete sprinkler ban was implemented, restrictions had an impact on trees, gardens and lawns, affecting both public and private green spaces. In some locations, long-established trees died and sportsgrounds remained without lawns. This caused a loss of amenity and recreational value in various public open and recreational spaces. ■ While the community generally supported restrictions, in some locations specific industry sectors (e.g. garden product suppliers and outdoor water-using businesses) complained that some industries were targeted but not others. ■ Restrictions became a politicized issue and despite community support, decisions were made on the basis of "never" having restrictions again. Decision-making would have benefited from more sophisticated consultation with the community on levels of service and trade-offs about restrictions.

DIY Water saving kits Kits containing regulators and aerators for showers and taps provided free of charge in public places such as shopping malls.	■ This was a cost effective initiative which achieved high participation rates and measured savings. ■ DIY water savings kits were particularly effective for engaging individuals who did not want a plumber to enter their home, or were skilled enough and preferred to change their own fittings.	■ This program can have the effect of 'cream skimming' or reducing the savings and cost effectiveness of larger, more comprehensive programs. ■ Unlike the audit program, or a compulsory swap of showerheads, the "DIY" nature of this initiative meant there was a risk that many of the kits were not installed.
Showerhead swap Participants typically exchanged up to two inefficient showerheads for free efficient devices obtained from various outlets, such as shopping malls, local council offices and hardware stores.	■ This was a cost effective initiative which achieved high participation rates and measured savings. ■ Because the swap required disconnection of existing showerheads, this provided a very effective way to ensure devices were installed.	■ This program can also have the effect of 'cream skimming' or reducing the savings and cost effectiveness of larger, more comprehensive programs. ■ In some areas, the program required households to provide a current water bill which excluded some renters. (There are varying regulations and practices in different jurisdictions about whether landlords or renters pay for water). ■ Consumer acceptability depends on quality of shower experience; careful selection of showerheads for swap programs is thus important to success.
Toilet replacement programs Typically, the program involved a qualified plumber replacing up to two single flush toilets with new efficient 1.2/0.8 gallon (4.5/3 liter) dual flush toilets with a rebate from a state government.	■ This was a relatively cost-effective initiative, although it had a higher unit cost than several other efficiency options, which achieved higher participation rates and higher measured savings. ■ Most major programs partnered with specific plumbing services and major toilet suppliers to reduce costs and provide a consistent products and service.	■ In the cases where a toilet was replaced in a secondary bathroom, or where programs allowed the replacement of older style dual-flush toilets, with new dual flush toilets, this had the effect of reducing the savings per household relative to the opportunity, and therefore the cost-effectiveness of the program

Washing machine rebate program Rebates were provided towards the purchase of a washing machine at point of sale for those machines with a specified minimum efficiency level.	■ This was a popular and cost-effective rebate program that overall helped to transform the "stock" of washing machines from inefficient models (often top-loaders), to front-loading efficient machines. These typically use half the water per wash. ■ Washing machine suppliers were at the forefront of helping to transform the market by supplying new, more efficient models. They were enabled by the increase in demand, due to widespread rebate uptake provided across multiple states. ■ Australia-wide consistent appliance water efficiency labelling, and later minimum water efficiency standards, aided the transition. Providing information to consumers (including campaigns by water companies) to raise awareness was key to success.	■ In early stages of the rebate programs less efficient machines were included. ■ Even with the significant shifts in stock (30% of machines were efficient front loaders within a decade, up from 10%) there is further, significant opportunity for water savings. ■ As the market shifted, more efficient machines became available at lower cost. This likely resulted in a significant proportion of free riders that limited the cost-effectiveness of programs.
Rainwater tank rebates A typical program involved scaled rebates for participants buying tanks ranging from 260 gal (1 kl) to 2,600 gal (10 kl). Additional rebates were available to incentivize connection to indoor end uses such as toilets and washing machines to optimize savings.	■ Very high rebate uptake, which, in combination with building regulations in most states that incentivized or required rainwater tanks, raised the prevalence in cities from 9% to 20% in less than a decade. ■ Rainwater tanks were effective in capturing water. They resulted in water savings in those locations where rainfall patterns in the location of use (populated areas) differed from the rainfall pattern in the location of rainfall (dam catchments), and where there was significant rain in said catchments. ■ Tanks provided other benefits such as capture of alternative water sources and reduction in stormwater runoff. ■ Restrictions and rebates aided voluntary uptake of rainwater tanks.	■ Many theoretical studies greatly overestimated the water savings that would be achieved. Savings were limited in locations where rainfall patterns in populated and catchment areas were similar, and/or where rainfall was very low. As a result, most rainwater tank rebate programs were not cost-effective. ■ Subsequent research indicates that there are problems with the longer term maintenance and functionality of tank systems, which also constrains water savings. ■ Poor configurations (e.g. roof area, small tank sizes, pump arrangements, mains switching devices) can result in low water savings and high energy intensity.

Targeting high residential water users This program targeted the top 10% of residential water users using over 37 gpcd (140 lcd). It involved a detailed water use survey sent to 79,000 households and follow-up personalized water plans advizing on how to save water.	■ A highly effective program which had the effect of significantly reducing the average water use per capita, due to the targeting of the top 10% of water users.	■ Further savings could have been achieved with more direct approaches (e.g. door-knocking) to providing information about water savings (e.g. as in WaterSmart in Western Australia). Now, with social media pathways, there could be more opportunities for change.
Target 140/ 155 An innovative, multi-media, multi-strategy communication campaign to encourage reduction in household water use to 37 or 41 gpcd (140 or 155 lcd in South East Queensland and Melbourne respectively) across all uses.	■ Successful in part due to the strong focus on research into the attitudes of the target audience and integration with other initiatives, including restrictions on outdoor water use, the (residential) high water users' program, non-residential sector water efficiency programs and rebate programs. ■ The 37 gpcd (140 lcd) target was achieved only four weeks after the launch of the program, 13 weeks earlier than planned, and awareness and recall of the messaging of the program were similarly successful. ■ The program design was subsequently replicated successfully in Melbourne as Target 155.	■ Difficult to measure savings due to timing, seasonal effects and interaction with other programs ■ After the drought ended, in SEQ Target 140 was replaced with 'Target 170'. A confusing aspect of the program was the subsequent messaging of 'Target 170' and that encouraged people to use more water, although after the drought ended water demand typically ranged between 40 and 53 gpcd (150 and 200 lcd) between the winter and summer months .
Waterless woks Program focused on Asian restaurants and provided subsidies to swap water cooled commercial kitchen wok stoves with waterless equivalents.	■ Waterless woks was a niche but innovative program demonstrating the effectiveness of collaborating with community groups that understand the water use patterns and communication needs of specific subsectors. ■ The water savings were achieved through audits and designing and manufacturing a technological solution. ■ Although only a small sector the savings potential for Asian restaurants swapping to waterless woks was up to 90% with a payback period of only one year even without financial subsidies offered.	

Business water efficiency management plans / water saving actions plans	■ Water utilities, in conjunction with state governments, successfully engaged businesses across sectors to assist them to develop and implement water efficiency/savings management plans. These plans were tailored to individual businesses and included an audit of water use, and identification of water saving initiatives. ■ In many locations these plans initially targeted the top water-using businesses in the state, and case studies were shared online. As the drought progressed, and residential users were subject to higher levels of water restrictions, business users (above certain quantity levels) were required to prepare and submit plans to water utilities. ■ Water utilities provided information and other knowledge-based support to industry to prepare these plans.	■ In some areas, the programs for business water efficiency management plans were under-resourced. As a result, although all businesses using above certain quantities of water were supposed to develop plans, this was not enforced.
Communication and promotion of water conservation and water savings	■ The communication, promotion and outreach elements of water conservation campaigns were pivotal to their success across jurisdictions. They also engendered and helped to maintain strong community support for water restrictions and other conservation measures. ■ Storage levels and consumption information were highlighted on websites, television news broadcasts, billboards, phone apps and other media. Information about water conservation and recycling was similarly distributed in bills, on websites, via schools and through the media.	

Pressure and leakage management Increasing investment in the inspection of water mains for leakage, improving responses to mains breaks, and installing pressure management equipment.	■ Low cost, no-regrets option when operating within the economic value of leakage control. ■ Strong community relations benefit associated with utility action and responsibility. Public interest in water use resulted in increased community interest and reporting of leakages, and quick response times.	■ Limited experience within some utilities increases the time to develop the necessary expertise.

SUPPLY-SIDE MEASURES

MEASURES	STRENGTHS	CHALLENGES
Access to dead storage Construction of pumps and infrastructure to access water below gravity off-takes within existing dams.	■ In 2006 in Sydney, dead storage was accessed which resulted in an increase in reliable system yield by 32,000 AF/a (40 Gl/a) (nearly 10%).	■ This option is only applicable in certain supply systems. ■ Marginal cost of supplied water is high because additional water is only used during severe drought. ■ Water at the bottom of the dam can be of poor quality and this can cause problems at water treatment plants.
Groundwater Construction of groundwater extraction infrastructure for long-term and/or emergency replenishment of water supplies.	■ Applied in Sydney in 2006 to obtain an additional potential alternative water source which was designed to operate only during drought, allowing the aquifer to recharge at other times. It was an illustration of the “readiness approach” to implementing drought responses. ■ In Perth, extended existing groundwater sources in combination with other non-rain dependent options were utilized as a means of supplying water in response to long-term climate change.	■ Marginal cost of water is relatively high if only used during drought. ■ High energy implications depending on the depth of groundwater. ■ Groundwater extraction poses environmental risks in some areas.

New inter-catchment transfers Construction of new pipelines and channels to transfer water from other catchments.	■ In South East Queensland the interconnection of water supply systems proved useful for increasing yield and reducing risk in some areas.	■ In Victoria, a significant investment of USD 1.4 B (AUD 2 B) was made in transfers from irrigated agriculture (savings from improving irrigation efficiency to be shared between irrigators, the environment and Melbourne). The infrastructure development was widely criticized in terms of the benefit-cost ratio and decision-making process.
Desalination Construction of seawater desalination plants for supply of water to coastal cities	■ In Perth, the desalination plant was used during drought to supply water. It reduced the need for further groundwater extraction (and possibly the associated risks). Currently, two desalination plants supply about 40% of Perth's water. ■ Introduces a rainfall-independent source of supply that can aid in increasing overall system reliability and drought security.	■ In many areas, large-scale desalination was implemented before more cost-effective water efficiency options were applied. ■ The opportunity to create smaller modular plants to help diversify supply from rain-dependent sources was missed in some locations. Several large-scale plants were being constructed across cities at the same time which, due to competition for resources and expertise, resulted in significant cost increases. ■ Some very large plants were built which are now idle and unlikely to be used until, or even well into, the next drought, representing significant stranded assets.
Readiness Preparing to build large-scale supply-side initiatives such as desalination and major reuse but only proceeding to construction if deemed necessary due to dam trigger levels.	■ Readiness concepts (real options) were applied in, for example, Sydney (desalination), SEQ (indirect potable reuse) and in Perth (groundwater).	■ In some locations, e.g. Sydney, the "readiness" was abandoned and large-scale infrastructure construction commenced ahead of planned water level triggers.

Major reuse Large-scale high quality recycled water treated for various sectors from residential estates to large industrial customers for non-potable purposes to offset potable water demand.	■ During drought, recycled water assisted in offsetting potable water requirements in both the residential (typically outdoor water usage provided through a third pipe arrangement) and non-residential sectors helping to slow the depletion of the potable water supplies ■ Useful in diverting effluent from sewage treatment plants for other purposes to protect sensitive receiving waters from nutrients. ■ In SEQ, recycled water schemes and the choice of technology were designed as a readiness strategy for indirect potable reuse. ■ In Melbourne, recycled water production from wastewater treatment plans was increased and supplied for a range of uses including agriculture, local sports grounds and public open spaces.	■ Significant government funding provided during the drought led to many non-financially viable schemes coming to fruition (Qld Pimpama Coomera, Qld Western Corridor, Sydney Rosehill) which are now closed or running sub-optimally financially post-drought due to reduced demand. ■ The stakeholder and regulatory arrangements varied across jurisdictions and in some instances caused significant barriers and delays to implementation. ■ Cost to produce recycled water often more than potable water hence post-drought value of recycled water diminishes along with demand. ■ Pop-up demountable sewer mining opportunities that could have been used to irrigate recreational open space were missed.
Indirect potable reuse (IPR)	■ Aquifer recharge in Western Australia for Perth is currently operating and has high community acceptance. There is also the capacity for the Western Corridor Recycled Water Scheme in SEQ to be converted to an IPR plant.	■ In Toowoomba in 2006, a community referendum resulted in the blocking of a proposed IPR scheme, due to poor community engagement. This had ongoing impacts for community and political acceptance of IPR across Australia.

Decentralized (building or precinct) wastewater reuse)	■ There are multiple triggers and drivers for decentralized approaches including drought policies that set recycling targets, state government subsidies and funding of recycling schemes, BASIX, and growing community and business expectations during drought for "smart" water savings developments. ■ Decentralized systems have significant potential for achieving avoided costs in new developments for sewage infrastructure. ■ Decentralized systems also provide the opportunity for integrating energy and nutrient capture. ■ Schemes which involve sewer mining have the potential to provide drought resilience for public open space and recreational areas, which would otherwize be subject to restrictions during drought.	■ There are complexities involved with designing and administering regulatory and licensing schemes for new private entities involved in the development of decentralized schemes. ■ There is a perception that energy usage can be high and this is the case in some schemes. However the actual energy implications of decentralized schemes depend on the basis used for comparison – e.g. whether the alternative is a gravity system, or requires pumping over a large distance, or desalination. ■ There were missed opportunities to take a system-wide approach to identifying the potential for decentralized systems. If assessed on an individual scheme-by-scheme basis and over a short timeline, it may seem more cost-effective to extend the existing centralized system than to support a new decentralized system. However, system-wide, and taking into account longer life-cycle maintenance and renewal costs of existing water and sewer infrastructure networks, decentralized systems prove to be cost-effective.

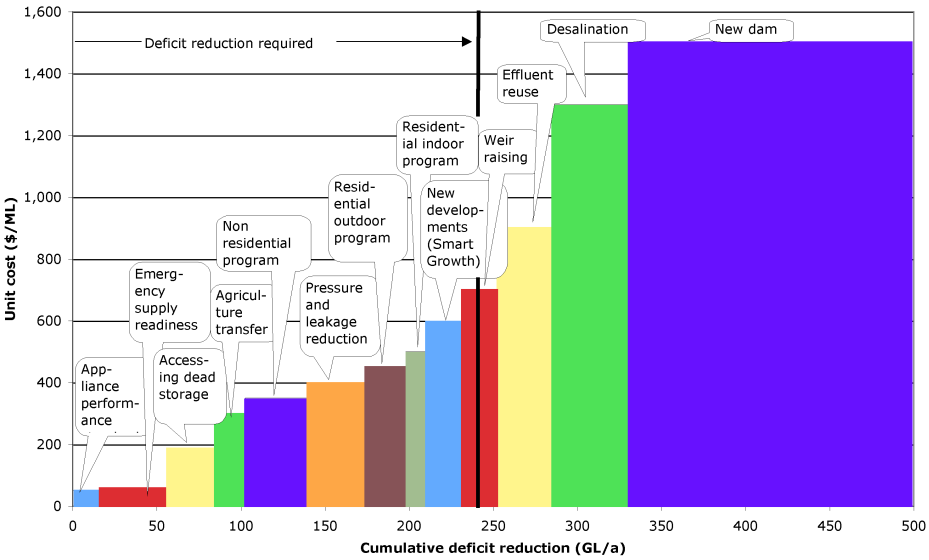
The list of measures above indicates the breadth of the measures that were implemented. It is useful, however, to be aware of the relative magnitudes of these measures, in terms of their contribution to water saved or supplied, as well as the relative unit cost. In addition, the energy and greenhouse gas implications of different types of measures are an important parameter, given the strong nexus between the water and energy sectors.

Table 0.1, and Figure 0.1 illustrate these parameters, for a range of measures, consolidated into type. These results are indicative, based on experience and the assessments done in a range of cities. For the demand-side measures these results and outcomes are quite consistent, however for supply options, such as dams, inter-catchment transfers and recycling schemes, it is highly dependent on the local situation. With those caveats, these results are useful to compare relative magnitudes of net contribution to reducing the supply-demand gap, unit net cost and greenhouse gas contribution, using typical Australian greenhouse gas intensity from a predominantly coal fired grid (1 US ton per MWh).

Table 0.1 – Indicative savings and yield, and unit cost and greenhouse intensity of selected supply- and demand-side measure types (adapted from White et al. 2008).

Category	Name	Water saved or supplied – potential in 2030 (thousand AF/year)	Unit cost (USD/ acre-feet)	Typical net greenhouse gas intensity (US tons/acre foot)
Demand	Appliance performance standards	13	60	-14.71
Demand	Non-residential program	31	390	-0.44
Demand	Pressure and leakage reduction	28	450	-0.18
Demand	Residential outdoor program	19	510	-0.18
Demand	Residential indoor program	10	560	-14.71
Demand	New developments (Smart Growth)	18	680	0.00
Demand	Effluent reuse	27	1,010	0.74
Supply	Emergency supply readiness	32	70	0.04
Supply	Accessing dead storage	24	210	0.00
Supply	Agriculture efficiency transfers	14	340	-0.07
Supply	Weir raising	16	790	0.00
Supply	Desalination	36	1,460	3.68
Supply	New dam	97	1,690	0.74

Figure 0.1 – Indicative savings and yield, and unit cost of selected supply and demand-side measure types (White et al. 2008).



➔Opportunities for California

Australia's Millennium Drought, which lasted for more than a decade in some areas, was much longer and deeper than California's drought has been so far. However, California is not yet in the clear. While there is a forecast of wet weather ahead, precipitation may not be in the right form (i.e. snow), in the right locations, or in sufficient amounts to bring about a measurable improvement in water conditions across the state. Moreover, climate change projections suggest that extreme events, like droughts, will become more frequent and intense in California.

In this section of the report, we reflect on lessons learned from Australia's experiences with the Millennium Drought and examine what these lessons mean for California's urban areas, which are the focus of this report.

Breadth of water efficiency programs

California is in the midst of its most severe drought on record. During the early stages of the drought, California Governor Jerry Brown asked Californians to avoid wasting water and voluntarily reduce potable urban water use by 20% from 2013 (pre-drought) levels. Initial actions to avoid water waste included asking utilities to set limits on watering and enacting modest prohibitions on, for example, washing sidewalks and driveways with potable water and allowing runoff when irrigating with potable water. In most areas, the voluntary reduction targets were not met. In response to worsening drought conditions, Governor Brown announced the first-ever statewide mandatory reduction in urban water use in April 2015 – calling on Californians to reduce potable urban water use by 25% from pre-drought levels. Water use varies dramatically throughout California, and the state set reduction targets for water suppliers serving 3,000 connections or more that ranged from 4% to 36% – with the largest reductions required for those areas with the highest residential per capita water use. Thus far, the majority of the state's water suppliers have met their individual targets, and the state is on track to achieve a total reduction in potable water use of 25% from pre-drought levels, saving over one million acre-feet of water from June to November 2015 (SWRCB 2016).

Water reduction targets varied considerably across the state, and local water utilities have implemented a range of measures to meet these targets.[1] Like Australia, California has reduced water demand through short-term conservation measures – that is, measures that rely on changed behavior, such as restrictions on the number of days lawns can be watered and calls for shorter showers and fewer toilet flushes. These types of conservation measures represent a fast and relatively inexpensive way to meet state-mandated reduction targets in potable water use and have helped reduce drawdown from surface water dams and groundwater aquifers.

Also like Australia, California has invested in efficiency improvements during the drought that will provide long-term reductions in water use, such as the state-run toilet and turf replacement rebate programs and many locally managed incentive programs. The most active programs have been those targeting outdoor water uses, which account for half of urban water use in California and up to 80% in some hot, dry inland areas. Lawn conversion programs have been especially popular, with customers paid from USD 0.50 to 5.00 per square foot of lawn replaced with low water-use landscapes. A recent survey found that the majority of program participants (90%) are residential customers (CUWCC 2015). While some water suppliers have operated lawn rebate programs for several years, many more are now providing these programs to their customers, and suppliers report that customer demand typically exceeds the budget available for these programs. Lawn conversion programs are providing both immediate and long-term water savings; they are also helping to transform the market by creating a demand for low

[1] It is of note that there are more than 430 large water suppliers (serving 3,000 connections or more) in California and several hundred more small water suppliers.

water-use plants and a workforce trained to install and maintain these landscapes and changing aesthetic preferences for urban landscapes.

Yet there remains significant potential to reduce indoor water use, and in California during the drought there has been inadequate attention paid to opportunities to replace old, inefficient appliances and fixtures in homes and businesses. A recent study by Plumbing Manufacturers International (2015) found that only 5.5% of an estimated 33.5 million installed residential and commercial toilets in California are high-efficiency models using 1.3 gallons (4.8 liters) per flush. Additionally, only 21% of lavatory faucets and 24% of showerheads meet the WaterSense standard of 1.5 gallons (5.7 liters) per minute and 2.0 gallons (7.6 liters) per minute, respectively. Similarly, Mayer et al. (2010) found that only 20% of households had clothes washers that used less than 25 gallons (94 liters) per load. Because the current building stock has a mix of old inefficient and new efficient devices, targeted outreach to high users would maximize the cost-effectiveness of indoor efficiency investments. California could look to Australia's indoor rebate and One to One programs to boost indoor efficiency efforts.

During and even before the drought, there has been far less emphasis in California on reducing non-residential water use, which accounts for about one-third of the state's urban water use. The non-residential sector includes the commercial, industrial and institutional sectors, and water savings from these users are not prioritized because of the diverse ways in which water is used and the belief that reducing non-residential water use would hinder economic development, especially as the economy in many areas is beginning to recover after the recent downturn. Several programs implemented in Australia could be implemented in California. For example, Sydney's water utility partnered with a local non-governmental organization working with ethnic communities to incentivize Asian restaurants to replace water-cooled woks with waterless models, each of which saved 1,300 gallons (5,000 liters) of water per day. In Queensland, businesses using between 0.8 and 8 acre-feet (987 kl and 9,870 kl) of water per year were required to install water efficient devices, such as low flow faucets, pre-rinse spray valves, and showerheads. Businesses whose annual water use exceeded 8 acre-feet (9,870 kl) were required to develop water efficiency management plans that accounted for water use, identified measures to reduce water use by 25%, and had a plan to implement those measures. Fines of up to USD 90,000 (AUD 125,000) were levied for non-compliance; however, to assist with compliance, rebates and incentives totaling USD $2.2 M (AUD 3 M) were provided to more than 2,000 customers.

Scale of water efficiency programs

Investments in conservation and efficiency programs have increased in California in response to the drought but are much lower than the investments in Australia during its Millennium Drought. Between 1990 and 2014, the Metropolitan Water District of Southern California (MWD), a regional wholesaler that sells water to 26 member agencies serving 19 million people across Southern California, invested USD 352 M (AUD 490 M) in water efficiency (MWD 2015). In response to the drought, the MWD dramatically boosted its conservation and efficiency budget to USD 450 M (AUD 625 M) for the fiscal years 2014/2015 and 2015/2016. MWD estimates that its member agencies will invest an additional USD 50 M (AUD 70 M), bringing the regional investment to USD 500 M (AUD 700 M) over a two-year period, or USD 13 (AUD 18) per person per year. Financial incentives in fiscal year 2014/2015 paid for the removal of 50 million square feet (4.65 million m^2) of grass, and the introduction of 215,000 high-efficiency toilets, 27,000 high-efficiency clothes washers, and 13,000 rain barrels. The MWD's investments are significant and will help to provide water savings long after the drought ends. The limited data available, however, suggests that similar levels of investment were not made in other parts of the state.

Across Australia, investments were much higher, and water efficiency efforts reached far more customers. The WaterFix program, for example, reached nearly half a million homes in Sydney, about a third of homes in the Greater Sydney area. Under this program, licensed plumbers would perform a household water audit, check for and repair leaks, and install efficiency devices, such as dual-flush toilets, showerheads, and faucet aerators. Customers paid USD 16 (AUD 22) for the plumber to visit the home plus an additional amount for any services rendered, and were allowed to repay the water utility for these services over a four-month period. A similar program in South East Queensland, costing USD 30 M (AUD 43 M), reached nearly 230,000 households, or one in six homes in the region, over a 10-month period. The estimated minimum value of the water efficiency measures in South East Queensland, excluding the leakage and pressure reduction programs, would be equivalent to approximately USD 110 (AUD 165) per person in today's values. This is approximately ten times the per capita investment in Southern California described above.

Diversifying the supply portfolio

As was seen in Australia, reliance on a single supply that is dependent on precipitation increases vulnerability to drought, and diversifying the water supply portfolio can help reduce that vulnerability. In response to the 1987-1992 drought, many Californian communities, especially those in Southern California, took steps to develop alternative water supplies, such as recycled water and brackish groundwater, and to expand their efficiency programs. The intensity of the current drought, however, is renewing interest in developing "drought-proof" supplies, including seawater desalination. Indeed, some water suppliers have sought reductions in their state-mandated water targets by developing new supplies, such as desalination (Stapleton, 2015).

Here, Australia provides some important lessons for California. Due to declining dam levels, Australia made massive investments in major new water supplies, including USD 7.2 billion (AUD 10 billion) in six seawater desalination plants and several recycled water plants. Today, in many cities, these plants have been shut down and represent stranded assets. Water customers are still repaying substantial capital costs but getting a minimal benefit. While these shuttered plants could be activated if needed (thereby providing a reliability benefit), the treatment technologies could also become obsolete before they are needed and may require significant investment to bring them back online, as has happened in Santa Barbara. These examples highlight the risks associated with building large, expensive new supplies to meet needs during drought periods.

A least-cost planning approach could help to avoid costly mistakes. Least-cost planning requires considering the full range of supply and demand measures and selecting the lowest unit cost measures first. Within this framework, measures that reduce demand should be compared on an equal basis with those that increase supply. As noted by the Western Australian Government (2003): "This is achieved by viewing water saved through water conservation as a resource, in exactly the same way water stored in a dam is regarded as a resource. Comparisons include the total costs and benefits to water service providers and the community, ensuring that *the water planning options implemented are those with the lowest cost to the community*" (emphasis added). It is of note that while traditional assessments look narrowly at the cost and benefits to the utility, least-cost planning takes a much broader view by also including costs and benefits to the community. This allows for inclusion of the co-benefits of projects, such as reductions in energy use and wastewater treatment costs or environmental benefits from efficiency programs.

Another way to avoid costly mistakes during a drought is to employ a readiness-based or real-options approach where possible. With this approach, specific water supply or demand measures are pursued when certain criteria are met. The appropriate approvals and permits are put in place beforehand so that implementation or construction of the measure can be initiated immediately, and there is sufficient time for the project to be implemented before it is needed. For example, Sydney's readiness strategy included a trigger to construct a desalination plant when dam levels fell below 30%, which would have allowed sufficient time to build the plant before reaching dead storage (White et al. 2006). Unfortunately, the readiness strategy was not followed through, resulting in the construction of a USD 1.4 billion (AUD 1.9 billion) desalination plant that was immediately placed in stand-by mode. Adherence to the readiness option would have resulted in significant financial savings, well over USD 1 billion, because only the funding needed for planning and permitting would have been committed, or the responsible agencies could have exited the investment at appropriate points by contractual agreement.

Regional integration

Water management systems in California are highly fragmented, with more than 400 water suppliers, each with at least 3,000 customer connections. The sheer number of utilities makes it difficult to coordinate activities and reduces the economies of scale when developing demand management programs and initiatives and in communications. While Australia generally has fewer water utilities, during the drought there were more than 20 councils in the South East Queensland region providing separate water services. In response, the Queensland Government established the Queensland Water Commission, which was given overarching policy, planning, and regulatory functions that allowed for the coordination of water use information, strategy development, and project implementation across formerly fragmented water supply services managed by individual councils.

In California, there are many initiatives, by government and the water industry, that are working in this direction. The state incentivizes utilities to participate in regional integrated water

management programs by providing them with access to bond-funded grant programs that they wouldn't otherwise be able to access. Likewise, water utilities in Sacramento, the San Francisco Bay Area, Santa Ana, and other areas, are trying to better coordinate their activities. The experience from Australia is that there is always a need for improved integration, coordination, and communication when drought response programs in most areas are led by individual water utilities.

Pricing and short-term revenue losses

Water utility managers are sensitive to the reductions in sales that have come as a result of drought response actions, and concerns about short-term revenue losses are a significant barrier to expanding water efficiency programs in California. Yet efficiency investments are typically less expensive than building new supplies. Various strategies are available to help utilities cope with short-term revenue losses, such as implementing drought surcharges, building reserves, and avoiding take-or-pay contracts.[2] Water utilities can benefit by improving their customer engagement efforts to build trust and educate users about water systems, the costs to manage those systems, and the long-term savings from efficiency investments. This was a missed opportunity in Australia, where the public support was achieved by the sheer scale of the communication and the urgency of the water saving investment, rather than a specific targeted campaign which explained the relative costs and benefits of different strategies.

Pricing mechanisms such as drought surcharges or fee-bates (rewarding low water users, increasing prices for high water users) were not implemented during the Millennium Drought. Community and customer representative groups raised important concerns about such mechanisms having the potential to disproportionately affect poorer households, or renters who had less capacity to install water-efficient fittings compared to home-owners. However, following the drought, prices were increased anyway – to pay for large-scale supply infrastructure. This presents a key opportunity for California to carefully investigate whether short-term drought surcharge incentives could be innovatively designed to address equity concerns, incentivize water savings during drought, and potentially avoid longer-term costs for customers.

Data and information

The Australian experience shows how important it is to have good data on water use, and on the impacts, costs and benefits of the available measures to increase supply and reduce demand. In South East Queensland, for example, aggregating the demand data for over 20 utilities was a large task, but made a huge difference in terms of managing the crisis. As is the case in many places, water data in California are limited. For example, as noted above, data on conservation investments are not readily available, and so it is difficult to evaluate the effectiveness of these investments. In response to the drought, the state now requires urban water suppliers with 3,000 or more customer connections (or those that provide more than 3,000 acre-feet (3.7 gigaliters) of water annually) to submit reports on water use and supplied population on a monthly basis. These data show large variations in per capita water use around the state and are being used to assess compliance with state-mandated reductions in potable water use. This is an important step in the right direction, but more is needed.

A lack of data can hinder efforts in the effective and efficient management of water resources. For example, if data on the market penetration of various devices, such as efficient clothes washers and toilets, are not readily available, planning for the rapid deployment of water efficiency programs is more difficult. Likewise, if data on the proportion of wastewater that is reused is not available for utilities across the state, this will curtail wastewater recycling. More and better data are needed. Additionally, consistent methodologies are needed to evaluate and verify efficiency savings to ensure that programs are as effective as possible.

[2] For additional resources to address this issue, see www.financingsustainablewater.org.

1. Introduction

California is experiencing an unprecedented statewide drought. To help manage this, legislation has been enacted and incentives offered to assist in curbing demand and increasing water system investment.

In recent times, Californian water managers from the federal to utility levels have sought to understand the experience in Australia in dealing with its worst-ever drought, the Millennium Drought, that gripped the nation for over a decade from the early 2000s until it officially ended in 2012.

This document represents a collation of valuable information and lessons gathered from the experience of the drought and its impact on urban water supply and demand in Australia, with the objective of assisting California in its time of need. As is the case in Australia, the vast majority of water in California is used for agricultural purposes, but the management systems and cost structure for urban water supply and demand are qualitatively distinct and separate. The key focus of this work is to explore the role of urban water efficiency within the context of water supply-demand planning and drought planning and management. While this report covers water supply measures, the emphasis is on water efficiency for two reasons. Firstly, in Australia it was the 'quiet achiever', saving more water, at lower cost and greater speed, than supply options. Secondly, while there has been much focus on the supply measures during the drought and after it ended, there has been less analysis and description of the experience of implementing demand-side measures and their role in reducing the impact of the drought.

The report aims, not to be exhaustive, but to be a "first port of call" for those wanting to know:

- what happened in Australia during the drought for some of the major cities
- how water managers responded
- what kinds of options were considered and implemented
- the scale of investment used and participation rates in efficiency attained
- what happened after the drought broke
- what are the key lessons (both what worked well and what could have been done better)
- how California might be able to take such lessons on board.

The study also aims to tell the story of the drought response, acknowledging that while much was done well, with hindsight, there were initiatives that might have been done differently.

This project was funded to support the greater water industry in California through the generosity of the following agencies:

- Metropolitan Water District of Southern California
- San Francisco Public Utilities Commission
- Water Research Foundation.

This report has been produced by the Institute for Sustainable Futures (part of the University of Technology Sydney, Australia) in collaboration with the US-based Alliance for Water Efficiency and the Pacific Institute. Input was provided by numerous Australian water industry stakeholders who worked through the Millennium Drought and have invaluable experience and insights into how to deal with drought, including project staff from the Institute for Sustainable Futures who were involved in supply–demand planning and drought response for utilities and government agencies in every mainland state and territory over the period of the Millennium Drought.

Note that units in the text are primarily US-based, except for graphs and tables, where conversions are provided in the captions. Costs are shown as US dollars, which have been converted from nominal Australian dollars using current exchange rates.

2. The Australian context

Australia is one of the driest continents on earth, and in recent history it has been affected by drought on many occasions. These droughts have been predominantly limited to specific areas. However, from around 1997 to 2012, Australia went through one of the worst droughts in its recorded history, the 'Millennium Drought'. This drought was different to past droughts because it covered much of Australia and lasted for a longer period.

In many parts of Australia, rainfall was far lower than average, as shown in Figure 2.1, based on data for the period 2001 to 2007.[3] The reduced rainfall significantly affected inflows to dams, which before the Millennium Drought provided the vast majority of water supplies for urban settlements in Australia. In Perth, for example, inflows fell significantly during the 1990s and were consistently below the long-term average. In the early 2000s, they fell even further, raising concerns that the region was experiencing long-term climate change (refer to Figure 2.2). Inflow patterns in other parts of Australia were similar, and dam water levels fell to record lows across the country.

Figure 2.1 – Rainfall from 2001 to 2007 relative to historical records

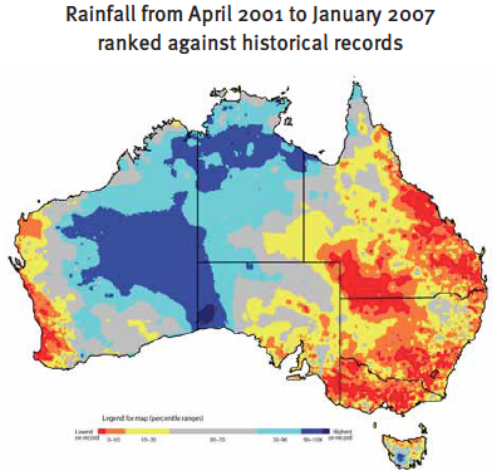
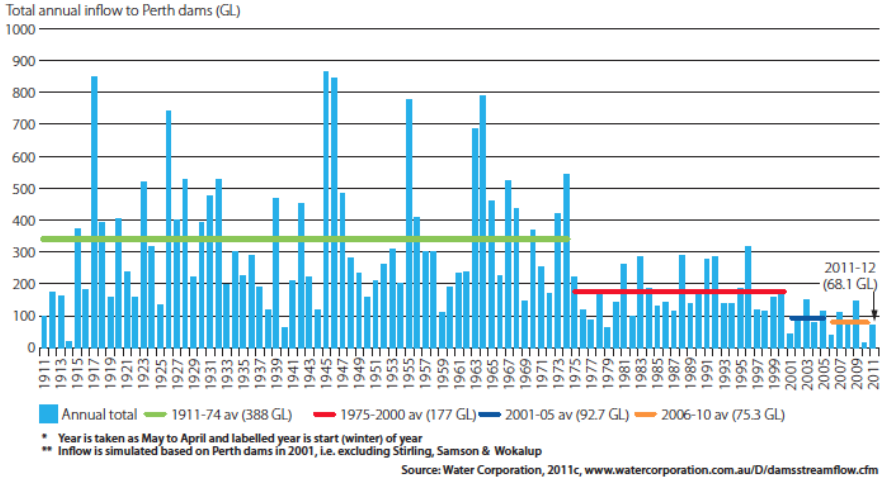


Figure 2.2 – Annual inflows to Perth dams (ATSE 2012)

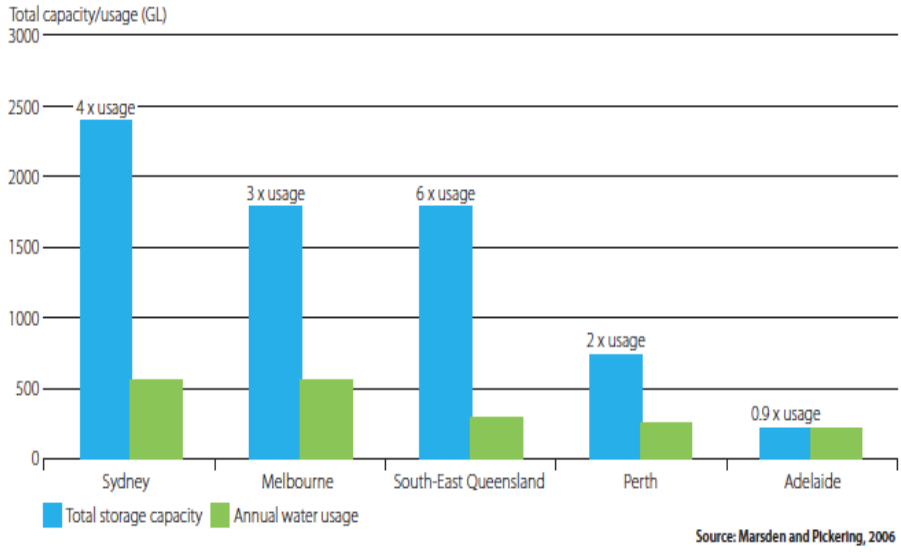
Note: volumes in gigaliters: 300 gigaliters = 250,000 acre-feet



The severity of the situation varied in each city depending on the degree to which it relied on dams as a water source, and on storage capacity of the dam compared to annual water usage, as shown in Figure 2.3. For example, Perth and Adelaide have less dam storage than other major cities and are less dependent on those dams because these cities extract large volumes of water from other available sources – groundwater and the Murray River respectively.

[3] https://www.longpaddock.qld.gov.au/about/publications/pdf/seq_drought_2007.pdf.

Figure 2.3 – Dam storage capacity relative to usage (ATSE 2012). Note: volumes in gigaliters. 1,000 gigaliters = 810,000 acre-feet



Perth was one of the first cities to experience falling dam levels during the drought. In other areas such as Sydney and SEQ, dams hit their lowest points in 2007 (33% and 16%[4] of their full capacity respectively), while Melbourne hit its lowest point two years later in 2009 (26%).

Falling dam levels raised concerns within the water industry that climate change was reducing inflows, water usage in Australia was too high, and the country was highly vulnerable due to its reliance on rain-dependent water sources. These concerns highlighted the need to reduce water demand through conservation and efficiency and diversify water sources through source substitution, major reuse, and non rain-dependent supplies, such as desalination. The gradual realization of the seriousness of the drought and Australia's vulnerability sparked a series of responses that included world-leading innovations, and both poor and exceptional examples of water planning and management.

Supply and demand planning

In some areas, consideration of ways to reduce demand and diversify water sources was relatively mature, and demand management and the use of best practice planning played central roles. Initiatives were implemented at the national, state, regional, and individual utility scales, ranging from new regulations to new planning tools and processes to realize water efficiency opportunities and pilot new programs.

At the **national level**, efficiency **labeling,** originally instigated in Victoria, was taken over by the Water Services Association of Australia (WSAA) in 1999. The voluntary labeling scheme was expanded in 2001 to cover more products and became mandatory in 2003 under the federal government's Water Efficiency Labeling and Standards scheme (WELS).[5] This means that all appliances and fixtures covered under the scheme, most domestic water using equipment, must carry the label showing their relative efficiency under standardized tests, and in some cases must meet minimum standards to be sold. The scheme assisted in providing a consistent terminology for water efficiency products, such as showerheads, toilets, taps, washing machines, dishwashers, and urinals. Water utilities and government agencies used this terminology when communicating with customers and when highlighting the efficiency of the products they advocated as part of their demand management programs. Later, Smart Approved WaterMark[6] provided a consistent labeling and certifying scheme for outdoor water efficiency products and other efficiency equipment not covered under WELS.

At the **state level, regulatory instruments,** such as the Building Sustainability Index (BASIX)[7] were adopted. The BASIX instrument required new households (and later refurbished

[4] https://papundits.wordpress.com/2011/01/20/wivenhoe-dam-levels-background-after-the-1974-flood/
[5] http://www.waterrating.gov.au
[6] http://www.smartwatermark.info/home/inner.asp?pageID=881&snav=3
[7] https://www.basix.nsw.gov.au/basixcms/ (accessed 4 January 2016).

households) to reduce their water usage by targets of up to 40% compared to a benchmark household usage of 65 gpcd (246 lcd). Targets were also set for energy use.

At the **utility level**, some regulators established water demand or efficiency targets, and some utilities set them for themselves. In the case of Sydney Water Corporation (SWC) the New South Wales State Government set a strong **target** to reduce total water demand, as a condition of a new operating license, which included reducing total water demand by 25% and 35% by 2001 and 2011 respectively, from the 1991 base level of 133 gpcd (503 lcd) (White et al. 2001). SWC's performance against these targets is reported annually as part of its operating license requirements.

To help determine what to implement at the **program level** to achieve its targets, SWC commissioned the first detailed **end use model** in Australia to assist in understanding how water was used at a detailed level, what options might be adopted to save water and achieve the required targets, and how such demand-side options compared in terms of costs and benefits to supply-side options using an integrated resource planning approach (White and Howe 1998; Turner et al. 2010).

SWC also began **piloting** demand management programs in 1999, including a residential audit program – Every Drop Counts WaterFix. This program was eventually implemented in nearly half a million homes in Sydney and has demonstrated significant water savings (Turner et al. 2005). The success of this initiative inspired other regions to adopt similar programs.

In other locations, including Perth, a similarly detailed understanding of demand was being explored at an end use level (Loh and Coghlan 2003), and Perth committed to significant demand management programs from early 2003. The washing machine **rebate program,** which was implemented in Perth between 2003 and 2009 and provided over 80,000 rebates provided in the first two years of the program, helped to rapidly transform the market due to the high demand for new, more efficient machines.

The exploration of how water is used and how it could be saved through demand management using the principles of integrated resource planning has had a **long history** in Australia, actually commencing in the 1990s in smaller more remote communities (such as Kalgoorlie Boulder where over half the households took part in retrofits and rebate programs). The knowledge in this case was brought from the US by Australian **champions** inspired by how demand management and integrated resource planning were being implemented in the energy sector in the US, leading to the first Australian national **Demand Management Guide** in the late 1990s (White 1998). The Guide was subsequently updated in 2008 and 2010 (Turner et al. 2008; Turner et al. 2010). Specific work was also undertaken in Queensland in the late 1990s, which set the scene for the successful implementation of demand-side programs during the drought (Maddaus et al. 2000).

This early demand management **knowledge** gathering and trialing in Australia, the broad-scale application of programs in larger cities such as Sydney and Perth, the national efficiency labeling, and the state-level regulation of new buildings, were inadvertently creating the foundations for a multi-pronged approach to understanding and managing demand. This approach utilized multiple instruments (i.e. regulatory, economic and educational) together with both technical and behavioral measures, which were all driving in the same direction. These foundations provided a springboard for the rapid expansion of planning and demand management activities that were to come as the drought intensified it was realized that demand management could play a significant and pivotal role in both short- and long-term planning.

Drought planning

Across the country, dams reached their lowest levels at different times and thus the urgency to deal with the drought varied from place to place at particular times. This allowed different cities to observe and replicate approaches as they saw fit. All of the major cities highlighted in this report:

- engaged in some form of strategic planning of their water resources during the late 1990s and early 2000s when the drought began to take hold, with Perth also demonstrating a high level of community engagement
- moved away from rain-dependent sources, although South East Queensland still considered constructing a large dam and Perth considered transferring water from a high rainfall area thousands of miles away until these options were ruled out for environmental and economic reasons, respectively

- implemented water use and reuse targets, although the exact wording around these and the level of difficulty to achieve them varied, with Sydney being the first to commit to an aggressive target back in 1995
- used restrictions to help cut demand as dam levels fell, with South East Queensland, for example, implementing a complete ban on sprinkler use, while Perth avoided such a ban
- committed to water efficiency in a major way although Sydney and South East Queensland made the largest investments to slow the depletion of the dams, and in the case of Sydney, with the expectation of water efficiency made a major contribution to the future supply–demand gap
- made significant investments in desalination and water reuse, with only Perth now currently using its desalination plants for base supply.

Below is a brief summary of how planning unfolded in each area, with further details provided in each of the individual case studies.

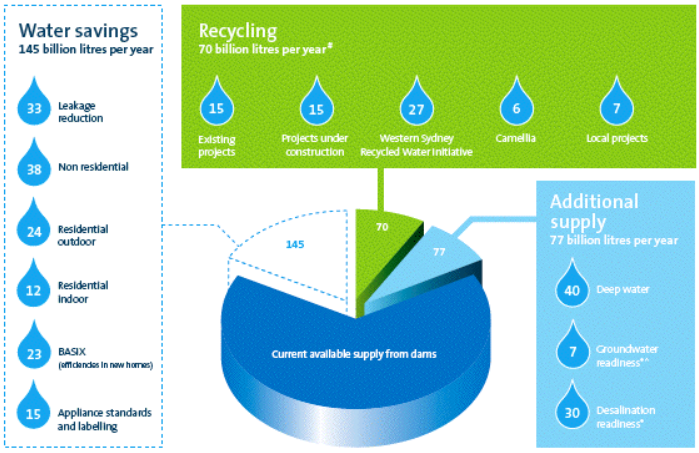
Perth, Western Australia

While **Perth** has major groundwater resources and is thus less reliant on dams, it had been suffering from significantly reduced inflows during the 1990s, a problem that appeared to be worsening during the early 2000s. This led to concerns about the effects of long-term climate change becoming a motivation for: investigations into drought planning; the reduction in the expected yield of the water supply system; detailed research into water usage; early implementation of large-scale demand management programs in 2003; investigations into additional groundwater reserves; and consideration of large-scale alternative supplies that would alleviate the need for stringent restrictions (seen as a significant political issue). One large-scale supply option – the construction of Australia's first major desalination plant – was completed in 2006.

Sydney, New South Wales

After developing the first end-use model in Australia, SWC piloted its first demand management program in the Shoalhaven, south of **Sydney**, in 1999. The SWC was going through a gradual process of testing and rolling out programs to assist in reaching its operating license demand management target. By early 2004, investigations were looking at what might need to happen for drought response as part of a metro-wide strategy, which later became the Metropolitan Water Plan 2004. In 2006, as the drought intensified, the Plan was further revized through government inter-departmental stakeholder consultation to greatly expand multi-sector demand management programs (residential, non-residential and non-revenue water) and recycled water, as required under the SWC operating license. It also included other emergency drought responses (see Figure 2.4). The Plan included, for the first time, a "real options" analysis and the inclusion of a readiness option, which meant that a commitment was made to fund preparatory work for a desalination plant at Kurnell in Sydney. The decision to actually build the plant would be delayed until a specified dam trigger level was reached that would allow sufficient time to build the plant before the dam reached dead storage, i.e. the level at which the remaining water in the dam could not be accessed without the need for additional pumping.

Figure 2.4 – Sydney water supply and demand measures (source: White et al. 2006)



Brisbane and South East Queensland

South East Queensland (SEQ) was in the throes of detailed supply–demand planning in the mid-2000s because of the significant and rapid growth in the area, resulting in the development of the SEQ Regional Water Supply Strategy. However, between 2004 and 2007 SEQ dam levels dropped from over 60% of capacity to less than 20%, and it was recognized that a strategy for short-term drought planning was needed. After significant multi-stakeholder planning led by the Queensland State Government, the Queensland Water Commission was set up in 2006 to oversee the management and implementation of the drought plan across the entire SEQ region. The Queensland Water Commission was responsible for managing the dwindling supplies, establishing water restrictions, and implementing a broad range of both short- and long-term water demand- and supply-side measures. These measures included rapid deployment of large-scale water efficiency rebate programs, the likes of which had not been seen in Australia, to slow depletion of the dam reserves. The measures also included construction of the state's first desalination plant and a major wastewater recycling system.

Melbourne, Victoria

In **Melbourne**, detailed visioning of water planning had taken place at a state level for a number of years, culminating in the 2006 Central Regional Sustainable Water Strategy that included targets for conservation and reuse and clarity about institutional roles and deployment of demand- and supply-side options. However, as the drought progressed further, rapid and adaptive decision-making was employed with significant reliance on restrictions for slowing the depletion of the falling dam levels as well as water efficiency initiatives. Large-scale supply options were also considered, including the largest desalination plant in Australia and the controversial North-South pipeline. Both of these schemes were eventually implemented at significant cost. After a change in state government and as rains returned in 2010, neither was subsequently used.

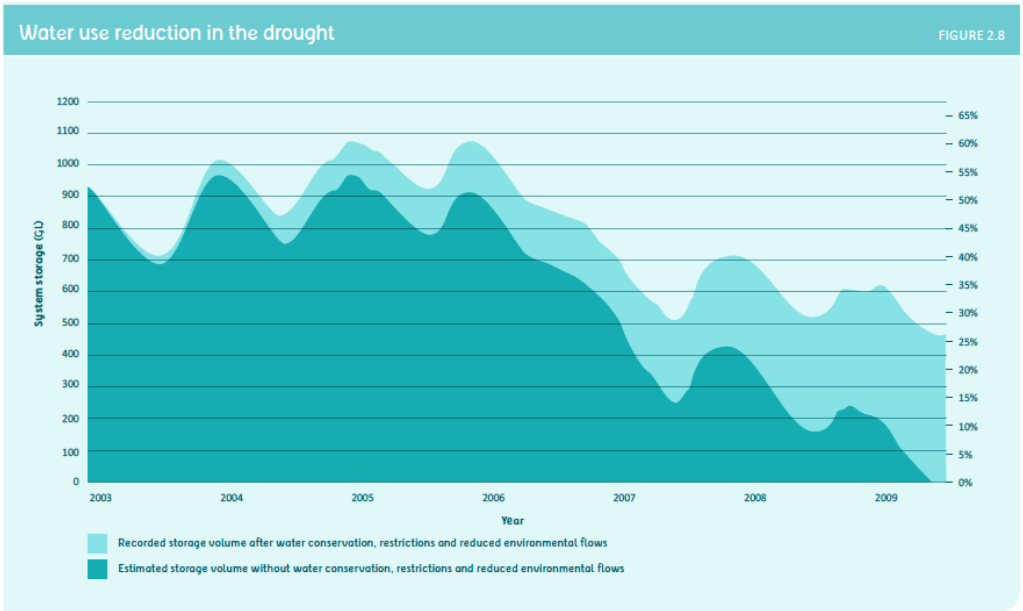
Demand-side measures

Demand management played a major and critical role during the Millennium Drought in terms of providing:

- significant water savings on a par in scale with new supply-side options, often at a fraction of the unit cost
- solutions that filled both the short- and long-term supply–demand gap, resulting in significant reduced demand over the longer term that post-drought has had limited bounce back, with most of the initiatives representing "no regrets" options
- additional time for water planners in various regions, which was invaluable in slowing the rate of depletion of the dams sufficiently to provide enough time to plan and develop additional supplies if required.

Figure 2.5 below illustrates how the combination of restrictions, water efficiency measures, and curtailed environmental flow releases from a minor storage assisted in buying time and preventing the city of Melbourne, with a population of over four million people at that time, from running out of water. Running out of water was a serious and real threat that was faced by several cities due to the severity of the drought.

Figure 2.5 – Historical Melbourne system storage and demand (source: OLV 2013)



This figure demonstrates that the water savings made by Victorians during the recent drought helped prevent Melbourne from running out of water.

Water use restrictions

Outdoor water use restrictions played a major role in curbing demand in Australia. Many cities had not implemented restrictions for decades, if they had ever done so. Nevertheless most stages of restrictions were well accepted by the community, even though, unlike water efficiency measures, they meant a different level of service, and under some restrictions such as a complete sprinkler ban, they placed vegetation and lawns at risk. In Australia restrictions predominantly focused on residential outdoor uses, such as watering lawns and gardens, washing cars, and filling pools, which in many locations, depending on climate, traditionally represented half of household demand. As restrictions became more stringent, non-residential customers were also affected. By the end of the drought, overall restrictions had run over a longer period, and had been more stringent, than in any previous drought. Further details on restrictions are provided in Section 3.

Water efficiency measures

The extent of demand management used across Australia during the drought is difficult to calculate retrospectively, as many of the records are not publicly available, or they are incomplete and/or are difficult to compare due to the changing nature of the programs implemented. It is also difficult to document the full costs of programs. Often, only a narrow government and/or utility perspective is articulated rather than whole-of-society costs and benefits, incurred by customers or other stakeholders. In the process of integrated resource planning (Turner et al. 2010) assessment of costs and benefits should be undertaken from the combined perspectives of the utility, government, customers, and other stakeholders to allow rigorous comparison of options. Surprisingly, many of the results of estimation or measurement of savings from programs have not been released publicly. Where they have been measured and the results released, the savings are often significant and the programs highly cost effective (Turner et al. 2014).

One long-running and well-documented program that illustrates the sheer scale of demand management programs implemented in response to the drought is the SWC-managed **Every Drop Counts** suite of programs. As part of its operating license, SWC was required to publicly report on the program annually. A breakdown of the individual programs that span the residential, non-residential and non-revenue water sectors is provided in the Sydney case study in Section 4. Between 1999 and 2011, with high participation and investment during the core drought years:

- Over USD 195 M (AUD 270 M) was invested in SWC programs focusing on the residential and non-residential programs, representing over USD 105 per customer connection.
- Annual reported water savings from these programs were over 32,000 acre-feet (40 GL)/a by 2011.
- An estimated USD 90 M (AUD 125 M) was spent on major leakage and pressure management programs, saving another 24,000 (30 GL) per year (SWC 2010).
- The largest participation rate was associated with the household audit and retrofit **WaterFix** program, which was implemented in nearly half a million houses, or approximately one-third of all houses supplied by SWC at that time (SWC 2011).
- The cost of that one program alone was USD 53 M (AUD 73 M) and is reported to have saved over 8,225 AF/a (10,100 ML/a) by 2011.

In contrast, the SEQ example illustrates the rapid investment, design, and deployment of demand management over a much shorter period, targeting specific sectors and subsectors (discussed in more detail in the SEQ case study in Section 4). SEQ was able to do this because they learned from the Sydney experience (Turner et al. 2005). In 2006, the **Home WaterWise Service** was launched over the 21 councils (later merged to 10) and included the successful rapid deployment of a retrofit program in which:

- State government and local councils invested over USD 32 M (AUD 43 M) with over 225,000 households taking part in two years. The target of 150,000 households within 18 months was reached nearly 8 months early (Coates and Bullock, 2008).
- The program was linked to the statewide **Home WaterWise Rebate Scheme** that provided USD 201 M (AUD 280 M) in subsidies for water-efficient devices ranging from showerheads to rainwater tanks.

SEQ also demonstrated world-leading programs in the form of:

- the USD 3 M (AUD 4.2 M) **Target 140** campaign, introduced during the stringent Level 5 restrictions, which encouraged individuals to reduce household water demand from 79 gpcd (300 lcd) before the drought to less than 37 gpcd, breaking new ground on the extent of behavior change expected of the community (later replicated by Melbourne as Target 155)
- the **One to One** water savings program, which focused on reducing the demand of residential high water users by providing customized residential water savings plans based on individual survey questions sent to 80,000 households with an extraordinary response rate of over 90%.

Supply-side measures

While demand management was gaining traction and being used to slow the depletion of water in the dams, major investigations were also taking place into a vast array of supply-side measures, including large dams, desalination plants, wastewater reuse, groundwater storage, storm water capture, aquifer recharge, and inter-catchment transfers. Other more innovative drought response options included accessing deep storage in dams and readiness options based on the planned ability to implement and build options on a contingency basis.

Dams

The proposed Traveston Crossing Dam, 62 miles (100 km) north of Brisbane, was included as a drought response strategy for SEQ in 2006, even though the water from the first stage would not have been available until well after 2012 and would have relied on rain-dependent sources. This highly controversial scheme, with an estimated cost of over USD 1.4 B (AUD 2 B) for stage 1 alone, was envisaged as a key part of a future proposed “water grid” for SEQ. The dam was eventually vetoed by the federal government in 2009, predominantly on environmental grounds due to ‘listed threatened species and communities’. Other minor schemes in the form of raising dam levels to increase volume were included in drought strategies and successfully implemented. Major dam modifications are shown in Table 2.1.

Table 2.1 – Large dam projects (source: PC 2011)

Location	*Project*	*Estimated cost*[a]	*Capacity*	*Completion date*
		$m	GL/year	
Melbourne	Tarago Reservoir reconnection and upgrade	97[b]	37.5	2009
South-east Queensland	Upgrade of Hinze Dam	395	310[c]	2011
	Wyaralong Dam	348	103	2011
Canberra	Expansion of Cotter Dam	363	78[d]	2011

[a] Costs were incurred in different years, therefore are not directly comparable. [b] Cost of the water treatment plant needed to reconnect the reservoir. [c] Expansion from initial capacity of 161 GL. [d] Expansion from initial capacity of 4 GL.

Desalination

Planning for the first large-scale desalination plant in Australia commenced in Perth at the end of 1999. It was finally announced in July 2004 that the construction of a 37,000 AF/a (45 GL/a) plant at Kwinana would proceed. The plant's output represented just under 20% of annual demand at the time it was completed in 2006. Almost immediately, a two-stage 100 GL/a desalination plant at Binningup was investigated due to continuing concerns over reduced inflows. The favored Yarragadee aquifer option was also considered, along with other supply-side options. In 2007 the Yarragadee option was dropped and construction of the Binningup plant commenced, with both stages completed by 2012 (Porter 2013). The Kwinana and Binningup plants are now capable of supplying 40% of Perth's current water demand.

Table 2.2 provides details of the major desalination plants constructed in Australia since 2006. A total of over USD 7.2 B (AUD 10 B) has been invested in these plants, which has contributed significantly to the recent increases in water prices across the country. The majority of these plants are currently in standby mode, representing large stranded assets.

Table 2.2 – Large desalination plants (source: PC 2011)

Location (project)	*Initial investment*[a]	*Capacity*	*Maximum expandable capacity*	*Initial (and expandable capacity as a percentage total water supplied in 2009-10)*	*Completion date*
	$m	GL/year	GL/year	%	
Sydney (Kurnell)	1 890	90	180	18 (36)	2010
Melbourne (Wonthaggi)	3 500	150	Up to 200	43 (57)	2012
South-east Queensland (Tugun)	1 200	49		25	2009
Adelaide (Port Stanvac)	1 830	100		80	2012
Perth (Kwinana)	387	45		18	2006
Perth (Binningup)	1 400	100		40	2012

[a] Costs were incurred in different years, therefore are not directly comparable.

Wastewater recycling

Water recycling had been used since the 1970s in many parts of Australia, and Sydney and Melbourne have water recycling targets. In combination with significant federal and state subsidies, these targets aimed to reduce potable demand, and they helped drive increased investment in recycling schemes during the drought. These schemes varied widely in scale and application and many took years to come to fruition due to the difficulties in the approvals processes. In many cases, the customer base shrank after the drought, and/or the systems were considered too expensive to operate compared to potable water (ISF, 2013). In some cases, like the iconic Pimpama Coomera residential scheme in Queensland, the recycling

plants were turned off after the drought ended.[8] Table 2.3 provides details of key large-scale recycled water schemes.

Large-scale water recycling has been implemented in virtually every major city in Australia as a result of the Millennium Drought. The largest is the 30,000 AF/a (36 GL/a) Western Corridor Recycled Water Scheme in SEQ, which was completed in 2008 at a cost of USD 1.9 B (AUD 2.6 B). It is linked to the water grid system, enabling water to be directed to power stations (the primary users), as well as industry and agriculture, and if necessary to provide an indirect potable reuse supply for Wivenhoe Dam, the major water supply dam for the region. In 2013, the plant was shut down to reduce long-term costs with start-up arrangements in place should the water be needed.[9] Like the desalination plants, this represents a large stranded asset.

There were large-scale subsidies available from state and federal governments during the drought, and whilst some of these were not well targeted, overall the support for recycling and investment in recycling technologies, and developing associated policies, regulation (including of private suppliers) and business cases helped to drive experimentation and innovation at various scales (ISF 2013). Decentralized systems grew in popularity during and after the drought, and there are now several precinct-scale systems that utilize sewer mining and feature water innovations as an iconic element of their development – both for the public, as well as private residents and investors.

Table 2.3 – Large water recycling projects (source: PC 2011)

Location	*Project*	*Estimated cost*[a]	*Supply/ Capacity*	*Completion date*
		$m	GL/year	
Sydney	St Mary's Replacement Flows Project	250	18	2010
	Rouse Hill Water Recycling Scheme	60[b]	4.7	2008
	Rosehill-Camellia Recycled Water Scheme	100	4[c]	2011
Wollongong	Wollongong Water Recycling Plant	25	>7.3	2006
Melbourne	Eastern Treatment Plant – Tertiary Upgrade	380		2012
South-east Queensland	Western Corridor Recycled Water Project	2 600	36[d]	2008
	Murrumba Downs Sewage Treatment Plant	197	11[e]	2010
Adelaide	Glenelg to Adelaide Park Lands Recycled Water Project	76	5.5	2010
Perth	Kwinana Recycled Water Scheme	28	6	2004
	Alkimos Wastewater Treatment Plant Stage 1 and Quinns Main Sewer	336	7.3	2010

[a] Costs were incurred in different years, therefore are not directly comparable. [b] Cost of the upgrade only. [c] Can be expanded to 7 GL. [d] Expected supply for urban water use. Total capacity is expected to be greater. [e] Based on 4 ML per day.

After the drought and emerging lessons

The drought broke at different times in different parts of the country but officially ended in 2012. By this time, restrictions had been in place for many years in some locations, and there had been significant expenditure on water efficiency initiatives. Regulations improved the efficiency of fixtures and fittings in new properties built during the drought, and demand management programs brought about structural changes in existing properties. The awareness campaigns and water restrictions led to long-term behavioral changes in water use. As a result, there was minimal bounce back in water demand after the drought ended, suggesting that many of the short-term drought response savings have been locked in over the longer term.

In all the major cities in Australia, there is now much less reliance on rain-dependent sources and a more diverse supply portfolio, which includes improved water efficiency, small-scale source substitution through stormwater and rainwater use, large-scale wastewater reuse, increased groundwater use and groundwater replenishment, and desalination. However, in developing this portfolio several issues have arisen:

- The construction of large-scale supply-side infrastructure, such as desalination, may not have been the best strategy, especially considering the extremes of

[8] http://www.goldcoast.qld.gov.au/environment/pimpama-coomera-waterfuture-residents-and-businesses-7904.html
[9] http://www.bom.gov.au/water/nwa/2013/seq/contextual/wateroverview.shtml

climate variability now observed and recent large-scale flooding in cities such as Brisbane and Sydney, resulting in the dams now being full and the large-scale supply-side measures not being required for years. There is now a large and diverse water supply system, but most of the desalination plants, in which USD 7.2 B (AUD 10 B) has been invested, are currently not in use, representing significant stranded assets.

- Similarly, some large-scale wastewater reuse initiatives, such as the SEQ's Western Corridor Recycled Water Scheme, have either been mothballed or are suffering from significantly reduced demand (ISF 2013).
- The overall cost of water services has increased substantially due to the need to pay for large capital expenditure during the drought.
- Many of the capital cities now have a higher energy intensity for delivering water than they did before the Millennium Drought because the higher proportion of recycled water, desalination plants and associated interconnecting pipe grids within the system require additional pumping (Cook et al. 2012).

Another concern is that while good planning was practiced during the drought, this planning was often negated by political decisions resulting in billions of dollars of unnecessary expenditure. This is a major concern amongst water planners and managers in Australia.

While demand management has been highly successful in reducing demand over the longer term and has contributed to short- and long-term savings, the investment in research, modeling, implementation teams, and the programs themselves, has been significantly curtailed since the drought ended. This is a major concern for water planners and managers in Australia because it means that potential savings are being eroded due to a lack of ongoing maintenance of programs, the absence of messages to customers about the need to keep water usage down, and the loss of the industry knowledge. These drought response elements will be essential when the next drought hits.

3. Measures in detail

In this section, a number of the measures that were implemented during or prior to the drought are described, providing in some cases more detail than in the previous summaries or case studies.

Restrictions

During the Millennium Drought, water use restrictions were in place in most capital cities and many regional towns across Australia. In most of these locations, restrictions had not been applied for several decades, or at such levels of stringency, if at all.

Restrictions focused on outdoor water use, particularly garden watering, car washing, cleaning of hard surfaces, and swimming pool use. They primarily targeted residential water users, although in some locations restrictions were also placed on non-residential outdoor water uses, such as irrigation of parks and sport fields, nurseries and market gardens, swimming pools, commercial car washes, and building and construction activities.

Restrictions were implemented as a “first contingency option” early during drought, as water storage levels declined. They were initially implemented at low levels – for example, reflecting basic and already well-accepted water conservation practices, such as not watering gardens during the middle of the day. As the drought intensified, progressively stricter restrictions were imposed, up to a total outdoor water ban in some places. Most places had 5 or 6 “levels” or “stages” of restrictions, but the rules in place at each of these levels varied between states, and for some states, between different water supply areas within that state.

Residential restrictions

- Garden watering – limits on the time of day and/or number of days a week; whether sprinkler use allowed; whether lawn watering allowed.
- Swimming pools and spas – filling of new pools was either banned or required a permit/ exemption with stipulations such as a pool cover; existing pools required a pool cover and/or a water conservation plan.
- Vehicle washing – restricted to spot cleaning and window cleaning with a bucket not a hose.
- Exemptions to these rules were in place for “seniors”, people with disabilities, or on the basis of medical or health requirements.

Non-residential restrictions

- Specific rules for non-residential industries or water users – e.g. on nursery and market gardens, public pools, commercial car washes, commercial poultry farms, food transport vehicles, sportsgrounds, building and construction, and motor vehicle dealers.
- Same rules applying for residential and non-residential users, with a scheme to apply for exemptions.
- Specifying rules and requiring development of water management plans.
- No specific rules, but requiring development of water management plans.
- No specific rules (even where residential restrictions are in place).

Examples of restrictions on residential garden water use during the Millennium Drought:

Sydney Level 3
- No sprinkler use
- Drip systems and hoses allowed 2 days/week, 4pm-10am.

Melbourne Stage 3a
- No lawn watering
- No sprinkler use
- Dripper systems and trigger hoses allowed 2 days/week in restricted hours

Perth Level 4
- Sprinkler watering allowed 2 days/week, 6pm-9am

Examples of restrictions on non-residential water uses
Melbourne Stage 3a
- Sportsgrounds and public gardens may be watered under restricted hours, or under an approved water conservation plan.
- Commercial nurseries, garden centres, and market gardens may use watering systems up to 3 hours per day with approval. Trigger hoses, buckets, and cans filled from a tap may be used anytime.

Restriction triggers

In locations predominantly supplied via surface water catchments, including Sydney and Melbourne, the "trigger" for introducing restrictions and for progressing to stricter levels of restrictions were linked to storage levels in dams. These triggers served as an operational guideline and also as an effective way to clearly communicate to the public the introduction of progressive stages of restrictions – and after the drought, the lifting of restrictions. In other locations, such as Adelaide and Perth, where there is a strong reliance on inter-catchment transfers and groundwater respectively, restriction levels were not linked to dam levels, and decisions to introduce restrictions were made adaptively over the course of the drought.

In places such as Melbourne and Sydney, a set of rules and trigger levels was established prior to the drought, based on estimates of savings and stochastic modeling (Yurisich and Rhodes 1999). Amendments were made during the drought, for example due to public, media and/or political pressure not to introduce a total outdoor water ban when dam levels fell beyond the planned trigger point for these restrictions; or, worsening drought and the need to introduce more restrictive rules than had been previously planned.

Communication and compliance

Building on and fostering a water conservation ethos: Water savings through restrictions were achieved by building upon a latent water conservation ethos in the community – stemming from successful campaigns over many decades to encourage water saving attitudes and behavior. Nevertheless, while many Australians held strong attitudes in favor of saving water, household water use prior to the Millennium Drought was particularly high compared to other tropical regions which were not usually subject to drought, and also in particular segments of the community. Water use behavior – in terms of social norms, as well as technologies – fundamentally shifted as a result of restrictions and other water conservation programs in place during the drought. After restrictions were lifted, in many locations demand did not "bounce back" to pre-drought levels.

Compliance through communication and education: Overall, there was strong compliance with restrictions rules. At the core of this compliance were comprehensive programs of education, awareness-raising, and promotion. Communication strategies included dedicated information mail-outs with water bills, websites, public advertizing, and publication of dam levels. Restrictions promotions were coordinated with promotion of other demand-side measures – such as conveying restrictions as a way to achieve the voluntary water use targets also in place during the drought. Although there were provisions for water utilities to issue on-the-spot fines to those breaching restrictions, these were rarely issued, with education-based letters more commonly issued. Spot-check monitoring of outdoor water use was undertaken by utilities, but compliance relied more on social pressure from within the community. Phone-in systems were also introduced where the public could for example report on neighbors' non-compliance. Generally, approaches to compliance sought to engender a joint sense of community-wide participation in water savings for the collective good, rather than focusing on the punishment of offenders.

Community acceptance

Numerous community surveys showed people supported restrictions (at levels less strict than a total outdoor water ban) and they were mostly perceived as "sensible" water use given the drought conditions. Overall most households thought restrictions were relatively "fair" because all residents had to comply with the same rules – compared to, for example, the regressive impact of a drought pricing measure. As detailed in the next section, however, concerns were raised by households, businesses, and municipal authorities about the impacts of restrictions.

Concerns and costs

Although there was generally widespread support for restrictions, costs and concerns were also raised.

Households: Restrictions only applied to utility-supplied water, and some people were concerned, on the grounds of fairness, that households who accessed groundwater, or could afford to install or purchase rainwater or grey water systems, were exempt. There were also concerns about the loss of amenity and health benefits due to the reduced quality of gardens, and less activity in undertaking gardening, due to restrictions.

Businesses: In some locations, non-residential water users who were subject to specific rules, thought there had not been enough consultation on the design of restrictions, and questioned why only outdoor water-using industries were targeted, e.g. if there were no other requirements for improving water management for all industries. The nursery, turf growing, and garden industries voiced particular concerns about market impacts from restrictions on residential users that discouraged gardening.

Public open space: Municipal councils recognized the need to conserve water and instituted a wide range of water-saving measures but many also raised significant concerns about the decline of parks and recreational areas. Impacts included the increased risk of injury (and hence liability) from sports fields that were no longer grassed due to restrictions on lawn watering; re-establishment costs; and the loss of in many places decades- or centuries-old iconic trees from parklands. There was also concern about the overall loss of amenity, liveability, and health benefits due to the "browning" of public green spaces, particularly where households' private gardens were also affected by restrictions.

Costs and politics

As the drought progressed, restrictions became central to policy dialogue and political debates about whether various state governments had effectively planned water supply systems for drought, what decisions to make during the drought, and how to best make them.

Cost estimates for proposed infrastructure solutions during drought were in the order of one to several billion dollars per city – and at the same time, "cost of restriction" estimates were also made of similar magnitude. However, extrapolating costs of restrictions to Australia from limited surveys or studies – that fail to take into account differential impacts that depend on the stage of restrictions, the climate and the context of water use – is methodologically problematic and often produces flawed results. Ultimately, towards the end of the drought some political announcements opposed restrictions on the basis that there should not be any limits to how consumers choose to use water.

Water savings from restrictions

Water savings from restrictions were estimated by comparing actual demand to water use "if restrictions had not been in place". The estimation of this reference case requires modeling to separate the impact of restrictions on demand from that of weather and other demand management programs. Sydney Water was one of the few utilities which estimated water savings for restrictions corrected for climate as well as separated from the impact of other programs that reduced demand. As shown in Table 3.1, significant water savings were achieved. Several other utilities estimated the combined impact of water restrictions and other water conservation programs.

Table 3.1 Water savings due to restrictions: Sydney (note 300 lpd = 80 gpcd)

Year	Actual water use (liters per person per day)	Estimated water use without restrictions (liters per person per day)	Savings due to restrictions (liters per person per day)
2005-06	341	400	59
2006-07	328	389	61
2007-08	306	378	72
2008-09	309	372	63

Source: Sydney Water (2011)

Lessons learned

Restrictions were instrumental in achieving water savings and critical in buying time, i.e. delaying the need for infrastructure construction. They were also one of a suite of measures aimed at engendering a sense of the importance of water conservation within the community. Water restrictions – despite the name – were not a punitive mechanism, but rather an educational and behavior change tool designed to dramatically reduce water consumption.

Restrictions on outdoor water use were a key pillar of a public promotion and education campaign to shift understanding and actions towards efficient garden and outdoor water use

practices and as a result they were highly effective in achieving water savings. Communities were generally supportive of restrictions programs during drought – that is, up to a certain level. This support eroded if restrictions caused significant long-term damage to trees in either homes or public parks, reduced "liveability" and recreational values of parks and sportsgrounds, or placed undue obligations on some water-using sectors, but not on others.

Since the drought, some locations have revised trigger levels, including the removal of trigger levels in some cases. On balance, although they provide certainty in terms of defining the level at which restrictions will be implemented, they also reduce the ability for water utilities to act flexibly to adjust to changing conditions during a drought.

Residential home audits

The first significant residential water audits were implemented in Australia in the mid-1990s in Kalgoorlie in Western Australia. Audits implemented over the years have varied to some extent but have typically involved, for a small fee, a qualified plumber going to a participating house and installing, where appropriate, a new 3 star (<9 l/s) water efficient showerhead, tap flow regulators/aerators on kitchen and bathroom sink taps, and a toilet cistern flush arrestor in single flush toilets. Minor leaks were checked and, where feasible, repaired and additional showerheads offered for an extra fee. Advice was often provided to customers by the plumber, and educational materials were provided. The results of the household audit were sometimes collated to assist in subsequent analysis and evaluation of savings. In Sydney, water savings from a large sample collected early in the program were found to be 5,500 gallons per household per year (21 kl/household/a) (Turner et al. 2005). Significant energy savings from such programs have also been measured. Various models have been used for implementation ranging from the use of a utility's own staff for audits and bulk buying of products to reduce costs, to tenders with local plumbing service providers, to contracting out the entire service to niche contractors.

Audit programs have been used extensively in Australia. The Sydney Every Drop Counts WaterFix program was the largest program implemented, with 80,000 homes participating in 2006/07 alone and nearly 485,000 households participating between 1999 and 2011 (Sydney Water 2011). As part of this program, SWC also partnered with the state government to provide audits to low-income households. The SEQ Home WaterWise Service was widely implemented during the peak of the drought, with just under 225,000 households visited in two-and-a-half-year period commencing with a rate of 1,500 households per week initially and rapidly increasing to 3,000 per week using a large team of trained plumbers (Coates and Bullock 2008). Uptake of such programs was highly dependent on the level of advertizing and the incentives offered. In Sydney, the cost to the utility of such a program was around USD 130 (AUD 180) with the customer paying only USD 16 (AUD 22). After the drought, several utilities offered little or no financial incentives to the household, significantly lowering participation rates.

Do it yourself (DIY) kits

This initiative focused on providing water savings kits containing regulators and aerators for showerheads and taps. Such kits, worth USD 7.20 (AUD 10), were often given out free of charge in public places, such as shopping malls. These kits were widely used in Sydney as an alternative to the audit program as a means of capturing those customers that did not want a plumber to enter their home or were skilled enough to change their own fittings. A drawback of the program was that many of the devices were not actually installed, thus lowering the overall savings of the program. In Sydney, for example, approximately a third of these kits were not installed.

Showerhead swaps

This program typically involved residential customers exchanging their old inefficient showerheads for a free, 3 star (<2.4 gallons per minute, <9 l/m) water efficient model by bringing their old showerheads and latest water bill to approved exchange points, such as water retailer offices, local government locations, postal outlets, and hardware stores. The exchange process, as opposed to just giving showerheads away, helped to increase the number of units installed in households. The largest example of this kind of program was in Melbourne, where 460,000 showerheads were exchanged between 2006/07 and 2010/11 by the three water

retailers. Measured savings in Melbourne ranged from 2,240 to 3,260 gallons per household per year (8.5 to 12.4 kl/household/a) (Turner et al. 2013).

Toilet replacement programs

Historically, toilets have represented a large proportion of indoor water usage in Australia. Since the 1990s toilet water usage has gradually reduced from a standard single 2.9 gallon (11 litre) per flush to the current 1.2/ 0.8 gallon (4/3.5 litre) per flush dual-flush toilet introduced during the peak of the drought. While regulations, such as WELS and BASIX, improved the efficiency of new and refurbished properties, toilet replacement programs during the drought focused on tapping into the water savings from these devices in existing households. Toilet replacement programs typically involved a one-stop shop approach, with a resident contacting the local utility and arranging for a qualified plumber to visit the house. The plumber would change up to two single-flush toilets with new dual-flush toilets with the option of paying for the service through their quarterly water bills.[10] The programs would typically offer a range of three models starting at USD 206 (AUD 300) in total for the new toilet and associated installation, which included a USD 72 to 144 (AUD 100 to 200) rebate from the state government. In some locations, seniors on fixed incomes were offered a toilet replacement at no cost. Many of the utilities used a partnership approach with a major plumbing service and toilet manufacturer. Sydney had one of the largest programs, installing over 28,000 toilets between 2008 and 2011 (Sydney Water 2011), with each toilet replacement saving an estimated 6,000 gallons per household per year (Tillman 2012).

Rebate programs

Rebates for water efficient devices were widely available across the country during the drought, with hundreds of thousands of individual rebates provided in each major city for a variety of products. The most common and popular indoor rebates were for showerheads, toilets, and washing machines (see details following). Common outdoor products included pool covers and subsurface irrigation systems to reduce evaporation. Rebates were also available for alternative water sources; rebates were extremely popular for rainwater tanks (see details following) and in Perth, for private backyard wells using superficial groundwater.

Some areas also offered rebates on smaller water efficiency products. In Melbourne this was provided as a ‘basket of goods’ for USD 22 (AUD 30) on products worth over USD 72 (AUD 100), including flow control valves, mulch, wetting agents, compost/mulch bins, moisture/rain sensors, garden tap timers, trigger nozzles, drip watering systems/weep hoses, temporary grey water diverters, shower timers, rainwater diverters, waterless car cleaners, and toilet flush interrupters.

Less popular rebates offered in various parts of the country, that struggled to gain numbers past the hundreds, included rebates for grey water systems, aerobic treatment units, and hot water re-circulators.

Washing machine rebates

Rebate programs for efficient washing machines, typically up to USD 110 (AUD 150) a machine, were very popular and a cost-effective means of saving water during drought by shifting significant inefficient stock within existing homes (only 10% were front loaders pre-drought) from top loading 37 gallons (140 litres) per wash to front loading 20 gallons (75 litres) per wash. Significant numbers of rebates were provided during the drought years as part of the state rebate program administered by the local water utility. In Perth alone, 80,000 rebates for washing machines were provided in the first two years of the program, rising to over 200,000 by the end of the program in 2011. The rebate programs across the country helped rapidly transform the washing machine industry with manufacturers providing more choice in efficient front-loading machines due to the new efficiency market developed with efficiency labelling and later minimum standards assisting in the transition (Fyfe et al. 2015). Savings varied depending on which washing machines were included in the rebate scheme but were typically in the range 4,700 to 6,000 gallons per household per year (18 to 23 l/household/a) (Turner et al. 2013).

[10] In some areas, older less efficient dual flush toilets were eligible for replacement, although this typically reduced water savings and thus the cost-effectiveness of these programs.

Key points

- Rebate programs for efficient washing machines were very popular and a cost-effective means of saving water during drought by shifting inefficient stock in homes.
- There was significant potential in the early 2000s with only 10% of homes with efficient front loaders that used 50% less than standard top loading machines.
- The rebate programs helped rapidly transform the washing machine market due to the sheer scale of the programs implemented (i.e. in Perth 80,000 rebates in two years).
- Efficiency labelling and later minimum standards aided in the transition but still only 30% of homes have front loading machines, so there are still considerable savings available.

Background

In the early 2000s only 10% of homes had efficient front loading washing machines, typically 20 gallons/wash (75 liters/wash). The remaining 90% were top loaders, typically using 37 gallons/wash (140 L/wash) (Fyfe et al. 2015). Hence the potential to shift washing machine stock from top loading to the more efficient front loading machines, that used 50% less water, provided significant potential savings for both short- (drought) and long-term savings.

The introduction of rebates to capture that potential and incentivize the purchase of more efficient machines helped transform (along with WELS) the washing machine market in Australia in less than a decade. While top loading washing machines can achieve higher efficiency ratings than current models do, they typically remain less efficient than front loading models. There has been a clear shift towards more efficient machines being available in Australia, with over 75% of machines available now being the more efficient front loaders – markedly different from the early 2000s.

Top loader sales are now mainly 3 star (weighted average 25 gallons/wash or 96 liters/wash) while front loaders are mainly a higher rating of 4.5 star (weighted average 17 gallons/wash or 66 L/wash). While the availability of more efficient front loaders has increased, more top loaders are still sold per year (375,000 versus 436,000) (Fyfe et al. 2015, p. 48). Over 30% of homes now have the more efficient front loaders (ABS 2011) indicating there is still significant potential for savings in homes. In 2011 minimum water efficiency standards were introduced whereby machines with a capacity of greater than 11 pounds (5 kg) must be at least 3 star and machines with a capacity of less than 11 pounds (5 kg) must be at least 2.5 star (Fyfe et al. 2015).

Description

Washing machine rebates in Australia aimed to raise the stock of efficient machines from only 10% observed in the early 2000s. The rebate programs typically involved advertizing by a water utility or government agency of a rebate for a washing machine at the point of sale. Retailers also advertized the rebates to incentivize customers to upgrade their machines and to increase sales. Such rebates were typically around USD 108 (AUD 150). The logic initially was that the rebate would provide the cost differential between an efficient and inefficient machine at point of sale, although this price differential changed over time. The early rebate programs (pre-2004) used the Water Services Association of Australia AAA rating scheme. After 2004 the Water Efficient Labelling and Standards (WELS) Scheme star rating scheme was used to assist customers to determine which washing machines were eligible for a rebate.

Examples

From 2003 to 2009 the Water Corporation of Western Australia (WCWA) provided USD 108 (AUD 150) rebates on 4A or higher washing machines (a lower efficiency rating than the current WELS 4 star rating) as part of the broader Waterwise Rebate Scheme administered by WCWA on behalf of the state government. In only two years, over 80,000 washing machine rebates were processed. By 2009, the end of the program, over 210,000 rebates had been processed. Estimated savings by WCWA were 6,870 gallons (26 kl) /household/a (Turner et al. 2005, p31). However, measured savings were found to be 3,960 gallons (15 kl) /household/a. The sheer scale of the rebate program in Western Australia assisted in shifting the market towards more efficient machines.

In 2003 Sydney Water Corporation (SWC) ran a washing machine pilot program offering a USD 72 (AUD 100) rebate on the purchase of a machine with a 4A or 5A rating (i.e. before the

current WELS star rating was introduced). The pilot was evaluated using statistical analysis and showed savings of 6,075 gallons (23 kl) /household/a. The evaluation showed there was a marked difference between the savings achieved by a conversion from a top loader to a front loader (7,925 gallons or 30 kl/household/a) and the savings achieved by a conversion from an older style front loader to a more efficient front loader (4,490 gallons or 17 kl/household/a) (Kidson et al. 2006). Based on this evaluation SWC ran the full program from 2006 to 2010 offering customers and tenants a USD 108 (AUD 150) rebate for purchasing a 4 star or above rated machine. This was upgraded several times eventually to a 5 star machine (SWC 2011. p.11). Between 2003 and 2010 SWC spent USD 23 M (AUD 32 M) on the program, processing over 186,634 rebate applications with an estimated saving of 4,755 gallons (18 kl) /household/a (SWC 2011. p.11 & p.38).

Lessons

- The use of the rating schemes was important to provide clarity for customers, utilities and retailers about which washing machines were acceptable under the scheme.
- The rebate schemes were highly successful in helping retire inefficient stock early and shifting the market towards higher efficiency machines but care is needed to judge when the market has shifted sufficiently to withdraw rebates to avoid free riders.
- The evaluation of the program in Sydney at an early stage indicated how savings from the program could be maximized and how retailers work with the rebates (i.e. some retailers were influenced by specific manufacturers rather than the savings objectives of the rebates programs).
- For maximum savings to be achieved it might have been better to be more vigilant about which machines were replaced (e.g. only less efficient or top loading machines) as savings achieved from replacement of front loading machines were less and customers with a front loader more likely to buy a front loader anyway (i.e. free riders).

Rainwater tank rebates

Key points

Rainwater tanks (RWTs) have long been used in Australia in rural areas and where town water supply is of a low quality. During the drought there were extensive rebate programs and building regulations for rain tanks, with considerable uptake. Actual water savings from rainwater tanks were low or mixed, as their effectiveness is dependent on specific rainfall patterns, roof sizes, rain tank size, and connected end-uses.

Background

Before the Millennium Drought the adoption of rainwater tanks in major cities was relatively low. In 2004 it was:

- 9% in capital cities
- 31% in the balance of the states/territories
- 17% Australia wide (ABS 2004).

In capital cities the adoption typically ranged between 4.8 and 6.4% with Adelaide being an exception (37.7%) with a high proportion of small tanks, due to the hard water supply.

By 2010 this had changed dramatically with tanks in cities more than doubling (ABS 2010) to:

- 20% in capital cities
- 37% in the balance of the states/territories
- 26% Australia wide.

The most dramatic increases were in Melbourne (rising from 6% to 23%) and Brisbane (5% to 38%) from 2004 to 2010 respectively (ABS 2004, ABS 2010). This major shift has been as a result of a combination of regulations and rebate programs.

Regulations

- Regulations have affected both new and refurbished buildings. For example,
    - The performance-based efficiency certification system in NSW where water efficiency targets associated with BASIX[11] require up to a 40% decrease in water usage (depending on climate zone and property type) compared to a pre-BASIX home benchmark of 24,000 gallons per person per year (90 kl/person/a) (65 gpcd or 247 lcd). BASIX also requires energy targets. BASIX was initially introduced in 2004 for new single dwellings in Sydney and subsequently expanded to more areas in NSW, other new residential properties and residential properties being refurbished (over a particular value). The installation of a RWT has often been considered one of the easiest ways to achieve this target thereby inadvertently driving RWT installation growth in new and refurbished residential properties in NSW.
    - In 2006/07 the Queensland Development Code (part 25) required that all new detached and semi-detached houses in Queensland should be fitted with a RWT, wastewater reuse system or stormwater reuse system to reduce water demand on reticulated town water supply systems. These regulations were modified on several occasions including specification of a range of targets for such water demand reductions ranging from 2,600 to 18,400 gallons per property per year (10 to 70 kl/property/a) depending on geographical location.[12] As for the BASIX system, RWTs were predominantly used to achieve such targets, driving RWT installation growth in SEQ, which was undergoing a significant population growth at that time. This mandatory requirement was repealed in 2013[13] by the Qld Commission Authority (QCA) after cost benefit analysis. Councils can now opt into the requirement.
    - As part of the broader Victorian Star Building Standard a 5 star system was introduced in 2005 requiring new homes (class 1 and 2 dwellings) to achieve a 5 star energy rating for the building fabric, adhere to maximum flow rates for showerheads and taps, and have a maximum water pressure of 73 psi (500 kPa). In addition, new houses (Class 1 dwellings) must install either at least a 500 gallon (2 kl) RWT for toilet flushing serviced by a 540 square feet (50 sqm) roof area or a solar hot water system, or be connected to a reticulated recycled water system where it is available.[14] In 2011 a 6 star rating system including home renovations and alterations of a particular size was introduced nationally, which maintains the RWT requirements.[15,16]

Rebates

In existing households (with the vast majority being single detached dwellings where space is less of an issue but also town houses and semi-detached dwellings) have predominantly been affected by rebates provided by various levels of government (federal, state and local) as well as individual utilities (often implementing rebates on behalf of state governments). For example,

- As part of the USD 9.3 billion (AUD 12.9 billion) Water for the Future plan, the federal government delivered a USD 180 million (AUD 250 million) National Rainwater and Greywater Initiative from March 2009 to May 2011.[17] The initiative provided rebates of up to USD 360 (AUD 500) for tanks over 1,000 gallons (4 kl) (USD 300 for tanks 500–1,000 gallons) connected to toilet and/or laundry end uses and could be claimed on top of other state and local rebates within a particular period incentivizing actions to connect the tanks to indoor end uses.[18]
- The New South Wales Government Home Saver Program in NSW (including the installation of over 52,806 tanks from 2007 to 2012).

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[11] https://www.basix.nsw.gov.au/basixcms/
[12] http://www.hpw.qld.gov.au/SiteCollectionDocuments/SP%204.2%20Water%20savings%20targets%20-%205%20December%202006%20(previously%20part%2025).pdf
[13] http://www.hpw.qld.gov.au/SiteCollectionDocuments/BuildingAndPlumbingNewsflash513.pdf
[14] http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0004/73237/ACIL5Star.pdf
[15] http://www.greenrate.com.au/6-star-rating-victoria.html
[16] http://www.greenrate.com.au/6-Star-Fact-Sheet.pdf
[17] http://www.environment.gov.au/topics/water/water-cities-and-towns/national-rainwater-and-greywater-initiative
[18] http://www.raincycle.com.au/iS_admin/files//factsheet.pdf

- The Victorian Government Home and Garden Rebates (more than 300,000 rebates since 2003 including a significant proportion of RWTs).

Lessons

- Typically there is a need to maximize indoor water end use connections such as toilets and washing machines to optimize water savings from a RWT system.
- Careful tank configuration is important (i.e. maximizing end uses, increasing roof area, appropriate tank sizing as well as careful consideration of pump sizing).
- There is a need to consider whether RWTs are appropriate in individual climate zones in terms of rainfall quantity and pattern versus tank size, roof area connected and specified end uses (rainwater tank simulation models can be useful to ascertain this).
- Energy use can be significantly affected by poor pump size choice and/or operation with low flow and/or intermittent individual end uses such as toilets and taps leading to the pumps running inefficiently. Pumps typically need to be designed for low flow rates as high flow rates only represent a small proportion of water used. The use of pressure vessels in the system can assist in improving and rectifying inefficient pump operation.
- Rain switches and similar devices that switch to potable water when the tank is empty have been reported as an area of concern because tank owners are unaware they are using potable water.
- Poor functionality due to lack of ongoing knowledge/care of system (pumps failing, blocked guttering) has been identified as a potential issue of concern for the few locations across Australia that have conducted such evaluation.
- In the few locations that have conducted water savings evaluations the savings being achieved are typically below theoretical/modelled estimates due to the design and connection issues outlined above (Turner et al. 2014).
- While RWTs have been proven to save water they are in most cases, when retrofitted to existing houses, a relatively expensive option in terms of unit cost, compared to other options.
- A combination of better installation practices and better information for customers about ongoing tank maintenance will assist in improving functionality, tank water savings and energy usage.

Residential outdoor watering programs

Climate and associated outdoor water usage varies significantly across Australia but typically ranged between a third and half of residential water use in detached houses, which dominate the residential sector. As restrictions were imposed during the drought, several jurisdictions turned to residential outdoor watering programs to assist residents to use outdoor water more efficiently.

In Perth, the Waterwise Garden Irrigators Program was launched in 2003, the same year as the state government rebate scheme administered by the water utility. The program was developed in collaboration with the Irrigation Association of Australia. Accredited irrigation contractors received training on water efficient design and installation of garden irrigation systems requiring at least two years' experience in the industry including a written exam before becoming accredited under the scheme. Under the initial program, accredited irrigators conducted assessments for customers at a reduced fee. A large proportion of these customers had work undertaken following the assessment. In Western Australia, due to the sheer scale of outdoor water use, the water utility worked extensively for many years with industry representative groups, local garden centers, and irrigation suppliers and specialists to set up partnerships, accreditation schemes and common Waterwise products and services to help customers understand how to make their gardens more water efficient.[19] These partnerships and accreditation schemes are still in place.

In Sydney the Love Your Garden Program was run between 2007 and 2010, with over 23,000 participants. The program focused on households with significant outdoor water usage. It

[19] http://www.watercorporation.com.au/save-water/in-the-garden

involved a qualified horticulturalist visiting a customer's home, calculating the amount of water the garden needed based on the area, plant types, soil chemistry and irrigation methods and identifying how water could be saved. Tools, such as tap timers, rain gauges and information tags on taps giving advice on water regimes, were provided along with a detailed assessment report. The service was valued at USD 130 (AUD 180) but was provided to the customer for only USD 24 (AUD 33) (USD 40 or AUD 55 for large gardens greater than 13,000 square feet or 1,200 m^2).

Target 140

Background

From 2004 to 2007 SEQ dam levels dropped from over 60% to less than 20%. In 2006 the state government set up the Queensland Water Commission to manage and oversee the implementation of a drought plan across the SEQ region to manage the dwindling reserves, restrictions and implementation of both short- and long-term water demand- and supply-side measures. These measures ranged from major water efficiency rebate programs to construction of the state's first major desalination plant and one of the largest water recycling plants in the world. A key component of the drought plan was the use of water restrictions. Restrictions were tightened to Level 5 in 2007, breaking new ground in terms of the extent of behavior change expected of the community. While moving to Level 5, the Target 140 campaign was introduced encouraging individuals to reduce household water demand to less than 37 gpcd (140 lcd) from pre-drought levels of 79 gpcd (300 lcd). With severe outdoor restrictions already in place, voluntary indoor water savings were seen as an opportunity. Other targeted programs such as the One to One water savings program were introduced at the same time to specifically curb the demand of the top 10% of high water users.

Program design

The program focused on voluntary residential indoor water saving practices, behaviors, and attitudes and asked residents to reduce their average water consumption to 140 lcd (37 gpcd). Overall the program aimed to:

- reduce SEQ water use by 10% by the end of 2007
- achieve 37 gpcd (140 lcd) by the end of August 2007 (within 5 months)
- generate 60% awareness amongst SEQ residents of Target 140 by August 2007
- achieve 50% recall of campaign key messages by the end of August 2007.

The program was based on behavior change principles aiming to assist individuals to move through the various stages of behavior change leading to action, namely: pre-contemplation, contemplation, preparation, action, and maintenance. The program relied heavily on understanding where the community was already at in terms of their behaviors and attitudes through the use of extensive social research. Issues that came through in the research strongly were restrictions fatigue, belief that businesses were major users (when in fact the residential sector was responsible for 70% of demand), and there was still a significant group of high water users with high socio-economic status that had not changed their behavior. The social research drove the design of the campaign, which ultimately focused on:

- understanding the problem (the water supply in SEQ region is at a critical level)
- being aware of regional consumption patterns (70% of demand residential)
- believing that small individual changes in behavior could in combination make a significant difference to the crisis.

The entire population of SEQ (2.3 million people) were targeted in the campaign but an additional segment, high water users, was also specifically targeted under the associated One to One program. The Target 140 campaign aimed to personalize the problem and individualize the solution to facilitate individual behavior change.

The program

Various techniques were used in the campaign and resources provided:

- powerful, pervasive imagery and messaging to highlight the issue, complemented with entertaining imagery and messaging to show what individuals can do to save

- regular imagery and messaging to let people know how dam levels and overall achievement of targets were tracking
- extensive mass media (TV, radio, newspaper, web)
- direct mail to 1.1 million households (4-minute shower timers, refrigerator magnets and educational booklets)
- a specific website with resources
- communication materials (billboards, brochures, fact sheets, posters)
- giveaways (shirts, face washers, magnets)
- media partnerships
- local stakeholder partnerships (utilities and local government)
- linkage with the rebate programs, One to One program and business programs.

The Target 140 campaign ran for 8 months, cost USD 3 M (AUD 4.2 M) and reached 2.3 million people (1.1 million households) at a cost of less than USD 1.4 (AUD 2) per person. Fifty-four per cent of the budget was allocated to advertizing to ensure consistent and engaging messaging across multiple channels to gain maximum outreach. Forty per cent of the costs went into the direct mail-out of shower timers and information booklets. The remainder went to market research, communication collateral, website and consultants. The program was highly successful in that in combination with other programs it more than doubled its target of a 10% reduction, with demand dropping from 47 gpcd (179 lcd) pre-campaign to as low as 34 gpcd (129 lcd) by the end of 2007 (mid-summer). The 37 gpcd (140 lcd) target was achieved only four weeks after the launch of the program, 13 weeks earlier than aimed and the awareness and recall of the messaging of the program were similarly successful.

Following the easing of the drought, target messaging was used, such as Target 170, indicating that SEQ had come out of the red zone but that individuals still needed to engage in water efficiency activities. The messaging of targets was similar to those used to warn of fire danger. Due to the success of the program in SEQ, Melbourne used a similar campaign, Target 155.

Lessons

- Target 140 was a highly innovative program using multi-media, multi-strategy communication approaches to encourage reductions in household water use across all uses based on behavior change principles.
- Target 140 was highly successful in part because it used research into the attitudes of the target audience to inform the design and determine how to best take individuals along the various behavior change stages to lead to action.
- The program integrated other initiatives, including restrictions on outdoor water use, the One to One residential high water users' program, non-residential sector water efficiency programs and the rebate program thus focusing on behavioral and structural changes.
- A potentially confusing aspect of the program was the subsequent messaging of 'Target 170' and above that encouraged people to use more water. After the drought ended water demand has typically ranged between 40 and 53 gpcd (150 and 200 lcd) between the winter and summer months.

- Due to the success of the program, the design was replicated in Melbourne as Target 155 during the peak of the Melbourne crisis in 2009.

Non-residential water efficiency management plans

The non-residential sector was seen as a conservation opportunity by all major cities during the drought. As water restrictions mostly targeted residential users (and in some locations, specific outdoor water-using business sectors), it was also crucial to garner overall community support for water conservation programs by securing participation by the business and industry sectors to save water.

Industry water conservation potential was targeted in numerous ways. A common approach was the use of mandatory and voluntary Water Efficiency Management Plans (WEMP) for businesses. Programs would for example commence by targeting the highest water using businesses in the city or state, and supporting them with planning and responses. Rather than being framed as constraining production, WEMPs were seen as a way to save water, save money, and for some businesses an important component of demonstrating their efforts to save water during drought and helping to secure their "social licence to operate". These businesses may have used their water savings as part of their corporate social responsibility strategy and marketing.

In SEQ, for example, the program targeted businesses using >10 ML/a (8 AF/a) and nurseries, public swimming pools, buildings with cooling towers, and areas using potable water to irrigate areas greater than 5,400 square feet (500 m^2). Such businesses were required to develop plans to demonstrate 25% reductions in water use or best practice. These measures were introduced under restrictions and as part of ongoing Permanent Water Conservation Measures and were enforceable under the Water Act 2000. The restrictions were lifted for large businesses in 2013.[20] Similarly, in Western Australia, all businesses and government agencies using over 17 acre-feet (20 ML/a) of potable water per year needed to develop a WEMP that detailed their water-using practices and water saving actions and initiatives and provided regular progress reports on savings achieved.

In Melbourne, all business and industrial customers were required to develop and submit to their water utility a similar "WaterMap" for each site using more than 8.3 acre-feet per year (10 ML/a). The program built on and extended the voluntary scheme that had been introduced in 2003, in which Melbourne's top 200 non-residential consumers developed water management plans in conjunction with their water retailers. During the drought, water retailers contacted, approached, and worked with a wide range of businesses across many water-using industries to promote water saving and assist users to save water during the drought. Since the end of the drought in 2011, water management planning have no longer been mandatory, but the retailers continue to offer the program on a voluntary basis.

Waterless woks

A targeted non-residential end use program initially established in Sydney and later adopted by Melbourne involved a program focusing on the installation of waterless woks. Wok burners are extensively used in Asian commercial kitchens. These burners generate significant heat and water jets, which typically flow continuously while the kitchens are in operation, are used to cool each stove top. A typical burner can use around 660 to 925 g/d (2.5 to 3.5 kl/d). The use of such burners can represent up to 75% of the water use in an Asian restaurant (Sydney Water 2007, p. 46). An alternative water efficient system is the waterless wok, which can save up to 90% of the water used in traditional wok stoves.

The program established in Sydney in 2003/04, which identified a payback period of only one year, initially had limited uptake until the Saving Water in Asian Restaurants Project, run by the Ethnic Communities Council of NSW, began in 2006. With assistance from state government funds, participating restaurants could receive up to USD 1,440 (AUD 2,000) towards replacement of an existing conventional wok stove or a USD 1,440 (AUD 2,000) grant plus the same amount as an interest-free loan (payable after a year). Through the use of a combination of the subsidies, qualified multi lingual environmental educators, Chinese and other language educational brochures and DVDs were distributed to program participants. Case study

[20] https://www.dews.qld.gov.au/policies-initiatives/water-sector-reform/queensland-water-commission

examples, and a website were also used. The program became highly successful, often spread by word of mouth to new participants.

Key points

- The program demonstrates innovation and the effectiveness of considering potential savings in the commercial sector using an end use-based approach.
- Although only a small sector the savings potential for Asian restaurants swapping to waterless woks was up to 90% with a payback period of only one year without financial subsidies offered under the efficiency program.
- This program also demonstrates the benefits of collaborating with small ethnic community groups that understand how best to communicate with specific subsectors.

Background

In 2003/04, as part of the Sydney Water Corporation (SWC) Every Drop Counts Business Program, research and associated audits of Asian restaurants in Sydney revealed surprisingly high water use when compared with other similar food preparation establishments. Following further investigations it was discovered that standard water cooled wok stoves typically use a high proportion of the water in such premises, up to 75% (SWC 2007, p. 46). This discovery led to the development of new technology, the waterless wok stove, and associated demand management programs in Sydney and Melbourne.

Description

In Sydney in 2003/04 when SWC discovered the significant water usage and potential savings available in Asian kitchens they led research into developing the waterless wok stove. At that time there were over 2,000 wok stoves in Sydney. It was estimated that if each saved 1,320 g/d (5 kl/d) this could represent significant potential savings of 2,920 AF/a (3,600 ML/a).

A trial was conducted on a 200-seat Yum Cha restaurant with an average of 275 customers a day using two water cooled wok stoves, each with two burners and associated taps. One stove was replaced at a cost of USD 3,600 (AUD 5,000). The associated water savings were over 1,585 g/d (6 kl/d). Based on water, sewer and trade waste charges at that time, the savings were over USD 3,600 (AUD 5,000) representing a payback period of only one year for the customer.

After a low initial uptake in 2004/05, the Saving Water in Asian Restaurants Project, run by the Ethnic Communities Council of NSW, began in 2006 and the program gained traction.

The program won multiple environmental awards for its innovation and achievements. The program was evaluated in 2010 and was found to save 715 g/d (2.7 kl/d) per restaurant. Average savings achieved were 0.75 AF/a (929 kl/a) for each restaurant (78% of their water use) for the 147 wok stoves replaced (average 1.5 wok burners per establishment). Although savings were lower than anticipated the overall savings were 78 AF/a (96,679 kl/a). The program went on to be implemented in over 270 restaurants[21] in Sydney. Due to the success of the program it was replicated in Melbourne.

Lessons

- Although only a relatively small sub-sector in some cities the water savings and cost-effectiveness of the program provide significant potential savings.
- Evaluation of the program identified that savings could be increased if it targeted: larger restaurants, those with a more Asian-focused cuisine, and those that operated for longer hours (e.g. in clubs, pubs, casinos).
- Contracting the implementation program out to the Ethnic Communities Council that focused on providing multilingual education and advisory services in combination with significant financial incentives was highly successful.

[21] http://www.ben-global.com/storyview.asp?storyid=9581758&sectionsource=&highlight=took&aspdsc=yes

Schools water efficiency programs

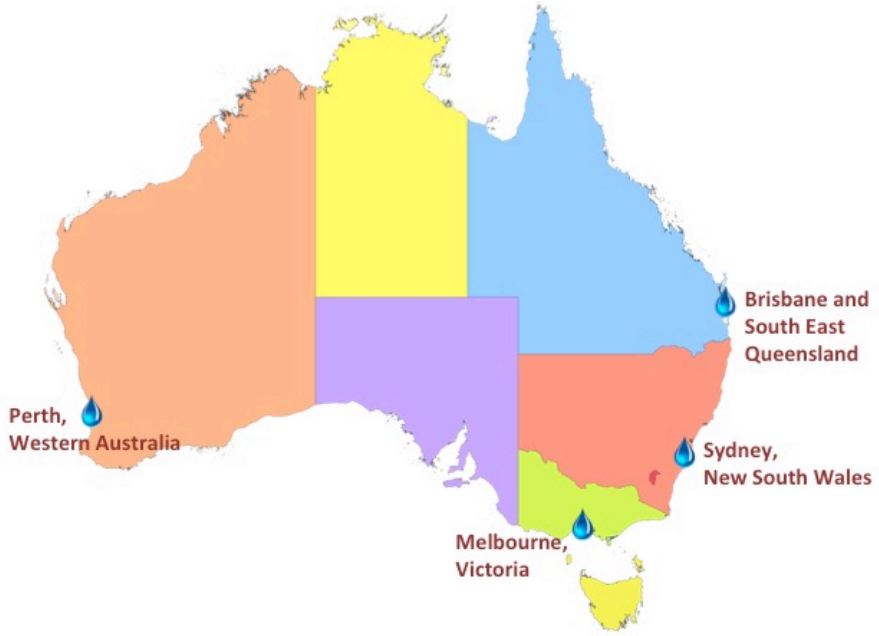
Most regions across Australia have engaged in some form of water efficiency program for schools for many years. These have ranged from developing education materials for children, assisting schools to find leaks through sub-metering and more recently smart meters, and in some cases assisting schools to upgrade inefficient appliances around the school premises and irrigation equipment and practices. During audits of schools, significant water losses and wastage have been found, providing significant opportunities in this sector. The implementation processes used are very broad, differing in each location and over time but typically include the utility working closely with government education departments and individual public and private schools.

A highly successful program demonstrating world leading attributes is the Victoria-based Schools Water Efficiency Program (SWEP). The program has been conducted in several stages after first being conceived in 2005 during the drought. Audits and retrofits were conducted from 2006 to 2010. After an initial voluntary phase the program became mandatory for public schools, leading to 1,739 participants of which over 1,600 were public. In 2012, the program progressed to the use of data logging and smart meter usage providing schools with the opportunity to access subsidized data loggers, web technology, specialist advice and curriculum materials for managing and monitoring water use and leaks with over 500 schools registered under the scheme by 2015 (Walker et al. 2014, Walker et al. 2015).[22]

[22] http://www.myswep.com.au

4. Case studies

This section provides case studies on the experience of four regions of Australia: Sydney; South East Queensland, including Brisbane; Perth; and Melbourne.



4.1 SYDNEY, NEW SOUTH WALES

Sydney is the largest city in Australia, with a population of 4.1 million in 2001 and 4.6 million in 2011. It has a temperate climate with warm, sometimes hot, summers and mild winters and an average rainfall of 48 inches (1.2 m).

The Greater Sydney water supply system, shown in Figure 4.1, consists of over 20 dams with a combined capacity of 2 million AF (2,500 Gl) (Turner et al. 2014). The large Warragamba Dam, with an operating capacity of 1.6M AF (2,000 Gl), accounts for 80% of this capacity.

Bulk water in the Greater Sydney area is managed by the wholesale authority, Bulk Water New South Wales (formerly the Sydney Catchment Authority).

Sydney Water Corporation (SWC), a statutory corporation set up in 1995 and wholly owned by the New South Wales (NSW) Government, is Australia's largest water utility, providing water, wastewater and major stormwater services to customers in the Greater Sydney area. The Metropolitan Water Directorate, created in 2003/04 due in part to the emerging drought situation, leads a whole-of-government approach to water planning for Greater Sydney and the smaller lower Hunter service area to the north.

The Metropolitan Water Plan inter-departmental stakeholder engagement process, led by the Metropolitan Water Directorate and instigated due to concerns over drought before Sydney's dams reached a low of 32% in 2007, has driven an innovative and diverse water service portfolio approach. Where once Sydney relied predominantly on rain-dependent dams, it now has a more diverse portfolio comprising dams, water recycling, comprehensive water efficiency programs, and a large desalination plant (albeit, like many others in Australia, currently in standby mode). The world-leading demand management and portfolio analysis undertaken in

Sydney, spurred on by the drought, has been replicated in other parts of Australia and internationally.

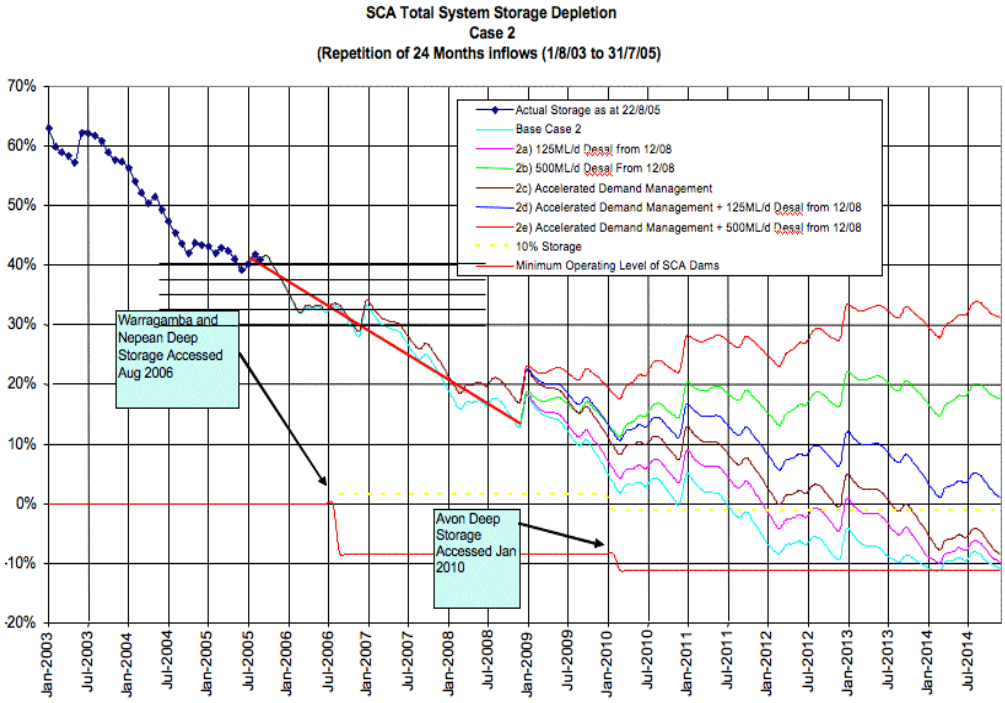
Water planning

SWC became a state-owned water corporation in 1995 while Sydney was going through a relatively short drought in the mid-1990s. The Independent Pricing and Regulatory Tribunal is the regulatory body that has oversight of SWC's license and the pricing of water in Sydney. Under its original license, SWC was required to reduce total water demand, including residential, non-residential and non-revenue water, by 25% by 2001 and 35% by 2011 from the 1991 base level of 133 gpcd (503 lcd) down to 100 gpcd (380 lcd) and 86 gpcd (329 lcd) respectively (Howe and White 1999). The license requirement, reviewed every 5 years, was established to ensure that customers do not pay for inefficient supply augmentation projects or face overly harsh or frequent restrictions, and that the supply–demand balance is managed efficiently. This set the scene for water planning in Sydney from the late 1990s.

In response to the aggressive target and commitment to demand management, SWC developed Australia's first major end-use model in the late 1990s. It was built to assist SWC to develop a detailed understanding of how water is used and what options could be implemented to achieve the required targets, and to compare the costs and benefits of demand management and supply-side options using an integrated resource planning approach (White and Howe 1998; Turner et al. 2010).

SWC set up the first demand management pilot in 1999. This pilot was the precursor to the Every Drop Counts WaterFix residential audit program that would eventually be rolled out to nearly half a million homes in Sydney (a third of households in the Greater Sydney area) and provide inspiration for similar programs in other regions. SWC was going through a gradual process of piloting programs to evaluate the cost and savings (Turner et al. 2005; Kidson et al. 2006) to achieve the demand management target when investigations in early 2004 began to look at what might be needed to respond to the drought as part of a metro-wide strategy. This strategy became the Metropolitan Water Plan in 2004. This was revised in 2006 as the drought intensified and the dam levels fell further. These investigations examined predictions of dam depletion curves using a monthly time step to determine how rapid deployment of demand-side and supply-side options could slow the rate at which the dam water levels were falling (refer to Figure 4.1).

Figure 4.1 – Modeled Sydney dam depletion curves considering various demand- and supply-side options

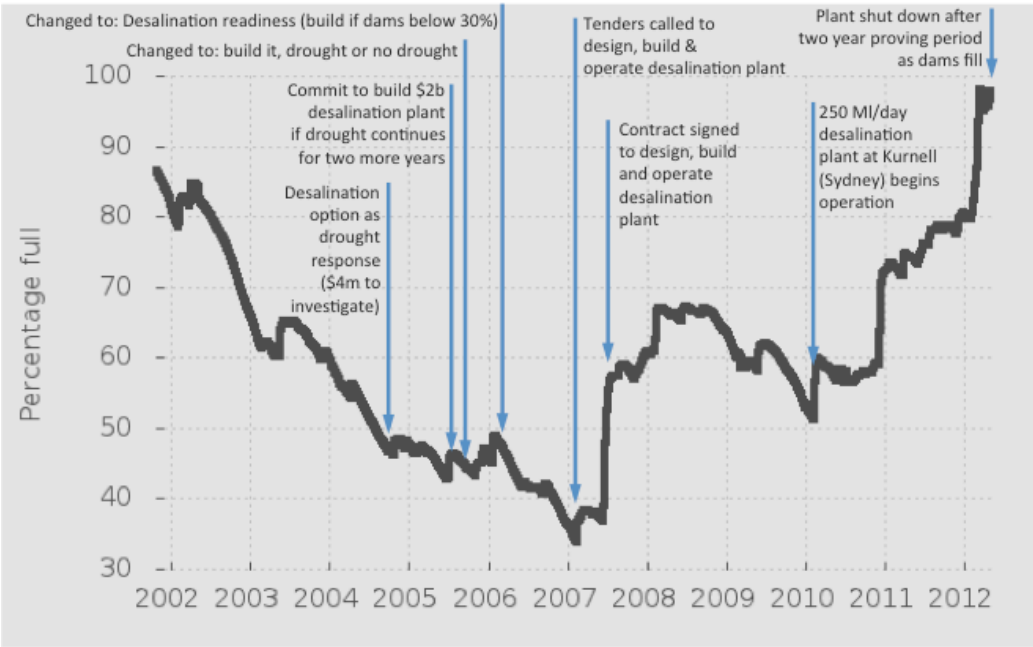


Demand management programs were seen as a way of providing more time for large supply-side options, such as groundwater reserves and desalination, to be considered, designed, and potentially implemented before existing major supply systems reached dead storage. Many of the demand management measures were also seen as 'no regrets' options, as they assisted in reducing long-term demand at a relatively low cost. The process of options investigation and portfolio analysis was undertaken with significant multi-stakeholder consultation and gave rise to significant commitments to water efficiency and recycled water as well as other emergency drought responses, including access to deep storage and tapping into ground water reserves. In addition, for the first time in Australia, real options analysis was applied in the development of a water strategy. A detailed assessment was made of a desalination readiness option. Under this approach the desalination plant would only be built when dam levels fell below a trigger level, which would allow sufficient time to build the plant before dams reached dead storage (White et al. 2006).

Decision-making

In Sydney, despite multi-stakeholder discussions and agreements, political intervention took over at critical points in the decision-making process. These decisions are well documented and provide useful lessons, as discussed later. Figure 4.2 shows the dam levels in Sydney over the drought period and the associated key decisions made with respect to the desalination plant.

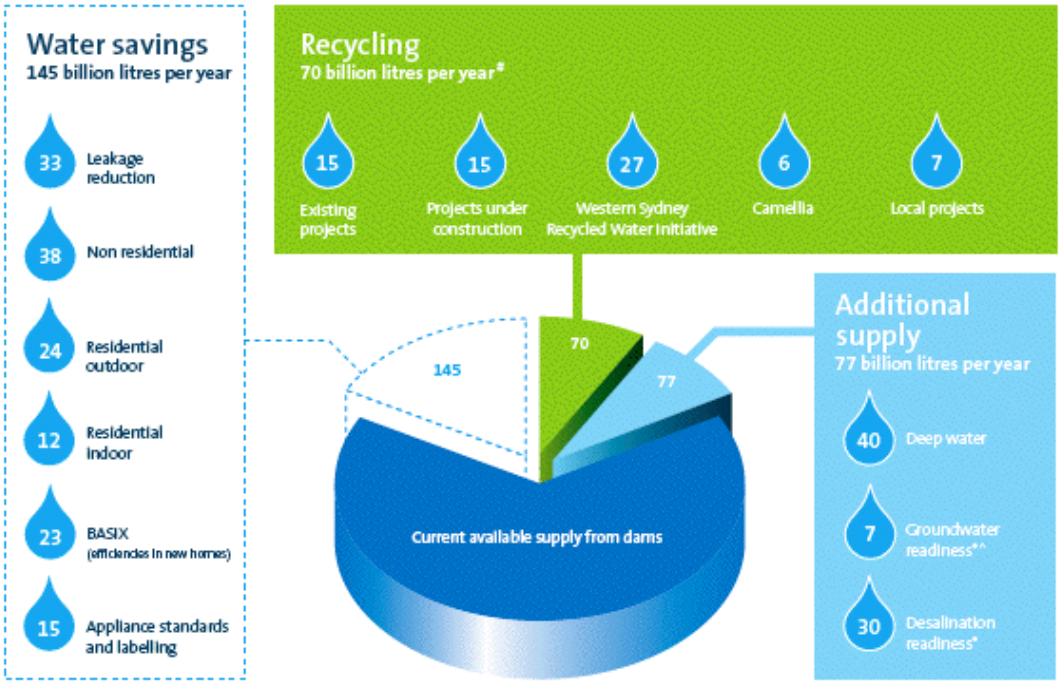
Figure 4.2 – Water planning decision-making during the drought (source: modified from Giurco et al. 2014)



In 2006, the commitment to build the desalination plant "drought or no drought" was put on hold when the government formally adopted the 2006 Metropolitan Water Plan review recommendations. These recommendations included the innovative 'readiness' strategy (White et al. 2006).

Figure 4.3 provides an overview of the portfolio of demand- and supply-side options adopted in the 2006 Metropolitan Water Plan. As shown, there was a significant commitment to water efficiency measures. For example savings contributions would come from: water efficiency programs (audit, retrofit and rebate programs) in the residential (both indoor and outdoor) and non-residential sectors; national appliance efficiency standards and the water efficiency labeling scheme (WELS); local regulations on the efficiency of new and refurbished buildings (i.e. the building and sustainability index – BASIX); as well as leakage and pressure management in the non-revenue water sector. The commitments to water savings through these demand management measures amounted to twice the savings that would result from the Plan's major water recycling schemes. The portfolio also included access to deep storage in dams and to limited groundwater sources as well as the desalination 'readiness' option.

Figure 4.3 – Water contributions of various initiatives to the Metropolitan Water Plan 2006 (source: White et al. 2006)



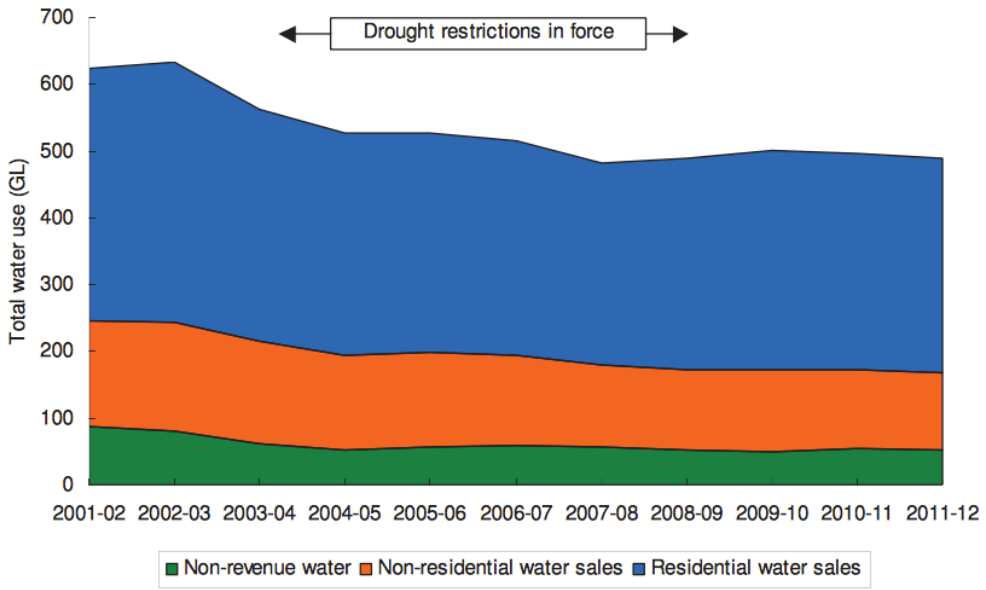
While the readiness strategy was formally adopted by multiple stakeholders involved in the Metropolitan Water Plan process, it was overtaken by political imperatives in 2007 when dam levels reached 34% and were dropping by 0.5% per week. Due to concerns that dam levels might approach the trigger level of 30% storage during the government's caretaker period (between when the state election was called and the date of the election), a decision was made to proceed with the desalination plant.

Shortly thereafter, it began to rain, and at the time the contract to construct the desalination plant was signed, the dam levels were at 55% and rising. By the end of 2008, dam levels were above 60% of capacity. By 2012, the desalination plant output was reduced during the testing period as rain caused Warragamba Dam to overflow. By the end of the testing period in late 2012, the USD 1.4 B (AUD 2 B) desalination plant was shut down, raising major concerns about the decision-making process and associated political intervention (PC 2011).

Water demand

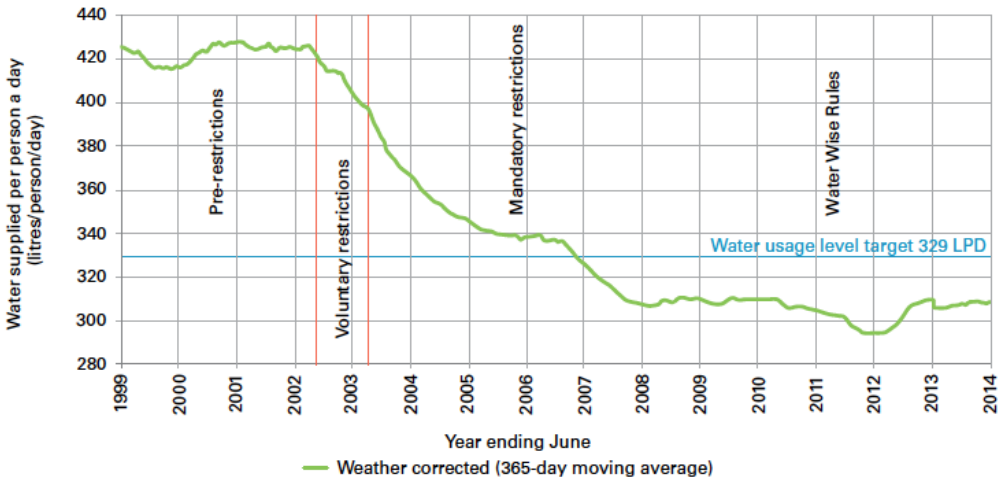
Prior to the drought, total water usage in Sydney was typically over 490,000 AF/a (600,000 ML/a), or 110 gpcd (420 lcd) with the approximate split in residential, non-residential and non-revenue water as shown in Figure 4.4.

Figure 4.4 – Historical water usage in Sydney by sector (SWC 2011 p. 93)



The license target for 2011 was 87 gpcd (329 lcd). As shown in Figure 4.5 this was achieved well ahead of time and the demand has remained below the 2011 target for over 7 years with limited bounce back despite restrictions being lifted and investment in demand management programs being significantly curtailed after the drought.

Figure 4.5 – Historical total per capita water demand (source: SWC 2014)



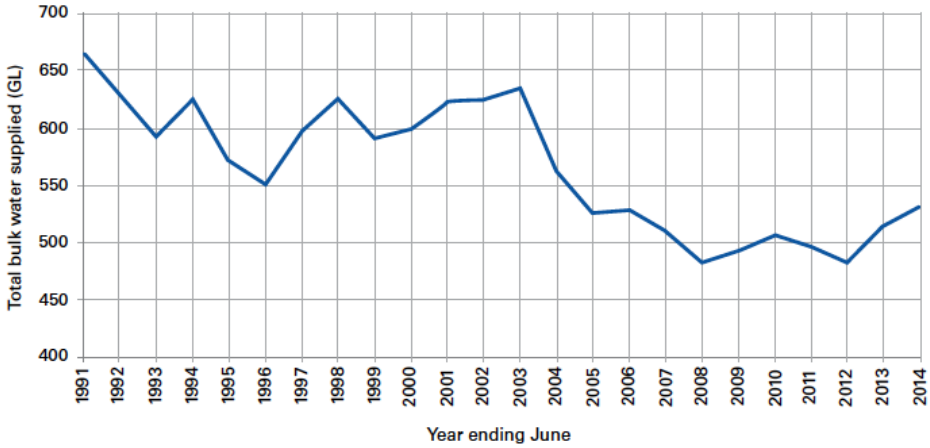
As shown in Figure 4.6, Sydney now uses less water than it did in the early 1990s despite the population rising from 3.7 million to 4.6 million. This is due to a combination of factors including:

- Improved toilet efficiency – Pre-1990s most toilets sold were large 3 gallon (12 liter) single flush units. In the early 1990s dual flush toilets became more common until, during the mid to late 2000s, the new efficient 1.2/0.8 gallon (4.5/3 liter) dual flush toilets, using a fraction of the water, began to dominate the market.
- Improved fixtures and fittings efficiency due to labelling – Efficiency labelling has been in place for decades in Australia but was taken up nationally in 2004 as part of the water efficiency labelling and standards scheme (WELS), which now covers the efficiency of toilets, showerheads, dishwashers, washing machines, taps, and urinals.
- Regulations and shifts in the market of products sold – Equipment such as toilets and washing machines now have minimum efficiency requirements, and due to the

high number of washing machine rebates taken up across the country as part of demand management programs the market is now dominated by more efficient models.

- New and existing BASIX refurbished housing regulations – From 2004 the building and sustainability index (BASIX) in Sydney and then NSW was rolled out requiring existing and then later refurbished properties to be up to 40% more water efficient than a baseline of 24,000 gallons per person per year or 90 kl/person/a) (reducing to a below 39 gpcd or 148 lcd). BASIX continues to apply today.
- Increased urban density – In 1991, 78% of households were separate, single-family houses, but by 2011, this was reduced to 61%, indicating the trend toward densification[23] and subsequent reductions in water use for turf (lawns) and gardens.
- Restrictions – Restrictions on outdoor watering and sprinkler use were in place in Sydney to varying degrees from 2003 to 2009 and were subsequently replaced with permanent water wise rules after the drought ended in 2012.
- The significant water efficiency programs for existing residential and non-residential properties (combining behavioral and structural changes) as discussed below.

Figure 4.6 – Historical total water demand in Sydney (source: SWC 2014)



Demand side

The reduction in water demand in Sydney has been significantly influenced by the SWC-led Every Drop Counts demand management program that ran for more than a decade (from 1999 to 2012). The program broke new ground in Australia in terms of its breadth (residential, non-residential and non-revenue water) and participation rates, with the WaterFix residential retrofit program reaching nearly half a million households (a third of households in the Greater Sydney area at that time).

As the drought worsened, restrictions were imposed in 2003 and gradually increased as dam levels dropped. Because the demand management program had already gained significant traction and was being implemented across various sectors, SWC was well positioned to increase the intensity and scale of the existing program as part of the drought response program of the Metropolitan Water Plan released in 2006. Table 4.1 provides details of key programs within the extensive SWC-run demand management program. The majority of uptake occurred during the peak of the drought.

The total investment by SWC in demand management, was well over USD 195 M (AUD 270 M) over the period 1999 to 2011, excluding the leakage and pressure management and recycling projects which were under separate parts of the license agreement. Additional smaller demand management programs were also implemented during the drought period by other organisations.

[23] http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/1GSYD

Table 4.1 – SWC key Every Drop Counts demand management initiatives

Initiative	Summary details	Estimated costs, uptake and savings
Residential		
WaterFix	From 1999 to 2011 households were provided with the opportunity to have a qualified plumber install a new 3 star water efficient showerhead (removing the old showerheads), tap flow regulators, and toilet cistern flush arrestor for single flush toilets and to repair minor leaks for a small fee of USD 16 (AUD 22). As at 2011 the service was offered to low-income households for free. Measured savings were 5,550 gallons/household/a (21 kl/household/a) (Turner et al. 2005)	AUD 72.5 M USD 52 M 485,211 10,144 ML/a 8,225 AF/a
DIY Water Saving Kits	From 2004 to 2011 the DIY kits were given free as an alternative to the WaterFix program. Customers could install simple devices to make existing showerheads and taps more efficient. Estimated savings were 1,770 gallons/household/a (6.7 kl/household/a)	AUD 7.1 M USD 5 M 211,623 785 ML/a 636 AF/a
Washing Machine Rebate	From 2006 to 2010 customers were offered a USD 108 (AUD 150) rebate for buying a water efficient washing machine, initially commencing in 2006 with rebates for 4 star-rated machines, which was subsequently modified to 4.5 star-rated and eventually in 2010 to 5 star-rated machines. Estimated savings were 4,750 gallons/household/a (18 kl/household/a)	AUD 32 M USD 23 M 186,634 3,558 ML/a 2,885 AF/a
Toilet Replacement Service	From 2008 to 2011 the service enabled householders to replace existing single flush toilets with a choice of three new 4 star-rated dual flush toilets with prices starting from USD 240 (AUD 330). Estimated savings were 6,070 gallons/household/a (23 kl/household/a).	AUD 15.5 M USD 11 M 28,224 558 ML/a 450 AF/a
Rainwater Tank Rebate	From 2002 to 2011 householders were offered a rebate to install and connect a new tank to existing homes not influenced by BASIX requirements. The size of the rebates depended on tank size and whether the tank was connected to indoor end uses such as a washing machine or toilet. Savings are estimated to be between 9,250 and 15,850 gallons/household/a (35 to 60 kl/household/a).	AUD 26.7 M USD 19 M 58,941 2,154 ML/a 1,745 AF/a
Love Your Garden	From 2003 to 2010 this program targeted households with high outdoor water use. It provided them with the chance to have a qualified horticulturalist review the water demand of their garden. A detailed watering plan was developed for each garden's needs and an array of tools was offered (i.e. tap timers, rain gauges and tap tags). The service, valued at USD 130 (AUD 180), was provided to householders for only USD 24 (AUD 33).	AUD 12.3 M USD 8.9 M 23,531 174 ML/a 141 AF/a
Non-residential		
Business Customer Program	This program ran from 1999 to 2013 and encompassed several business programs. Sydney Water supported large water-using business customers in the industrial, commercial and institutional sectors to achieve water and cost savings, by applying industry best practice and efficient	AUD 84.5 M USD 61 M Not reported

Initiative	Summary details	Estimated costs, uptake and savings
	management practices in day-to-day operations. Numerous best practice guides were developed as part of the program for sectors such as hotels, clubs and commercial laundries.	22,577 ML/a 18,300 AF/a
BizFix	From 2009 to 2011 this program assisted business customers to retrofit water efficient fittings in bathrooms and kitchenettes. 50:50 co-funding was provided. The program assisted 327 business sites to identify water savings and by 2011, 203 businesses had implemented actions to achieve water savings estimated at 1.45 AF/site/a (1,800 kl/site/a).	AUD 1.6 M USD 1.2 M 327 373 ML/a 302 AF/a
Smart Rinse	From 2006 to 2011 this program offered free replacement of inefficient pre-rinse spray valves with efficient models. The program targeted both commercial kitchens and retail food shops. Over 4,700 spray valves were provided to business customers. Estimated average savings were 0.2 AF/unit/a (253 kl/unit/a).	AUD 3 M USD 2.2 M 4,707 1,189 ML/a 965 AF/a

Another large and highly effective efficiency program that SWC implemented was a leakage and pressure management program in which it invested around USD 90M (AUD 125 M) between 1999 and 2011 (USD 90 M). During the peak of the drought SWC inspected virtually the entire 13,050-mile (21,000 km) network each year. This, together with pressure management, improved response times for repairing leaks and improved flow metering enabled SWC to meet its specific operating license leakage target of 85 +/- 13 AF/d (105 +/- 16 ML/d), which was incorporated into its 2005 to 2010 license after assessment of the economic level of leakage (SWC 2008, p. 25).

SWC was also involved in many smaller programs including: the Top 100 Monitoring Program looking at the water efficiency of customers using > 26,000 gallons/property/day (100 kl/property/day); council partnerships to help small and medium water-using businesses save water by employing project officers to work across council areas and conduct audits and give advice (500 businesses involved); the HiRise Pilot Program looking at the efficiency of high rise commercial/retail buildings (30 buildings); the Every Drop Counts program in schools which involved using smart meters to identify leaks (126 schools involved); the top 100 schools program which changed out inefficient devices with a saving of 192 AF/a (237 ML/a) in only 26 schools at a low cost of USD 72,000 (AUD 0.1 M); Rainwater Tanks in Schools where tanks were fitted and connected to toilets and irrigation systems; and the highly innovative waterless woks program (refer to Section 3).

Although not reported in the SWC suite of programs, SWC was also heavily involved in the Irrigation and Landscape Efficiency Project. From 2009 to 2011 the Australian Government, as part of its Water for the Future program, funded a Hawkesbury-Nepean River Recovery Program to improve the health of the river. SWC worked with the Recovery Program to implement the Irrigation and Landscape Efficiency Project, which looked at the open spaces (parks and sporting facilities) in the greater Sydney region irrigated with potable water. The project aimed to improve water efficiency by improving soil condition, irrigation technology and management practices. Sixty sites participated. At the assessment stage government participants received an assessment free of charge, while commercial facilities received 50:50 funding assistance from the government. During the implementation stage, 50:50 funding assistance was provided by government.[24] The program cost USD 5 M (AUD 7 M) and saved 885 AF/a (1,090 ML/a).

[24] http://www.environment.gov.au/water/policy-programs/water-smart/projects/nsw27c.html

Supply side

On the supply side, a range of options were considered during the drought including: accessing deep storage in dams, 32,430 AF/a (40 GL/a); accessing groundwater reserves (considered as a readiness option); major water recycling projects, typically for larger industrial users; and the innovative desalination readiness option.

The readiness option required that only the funds needed to gain appropriate approvals and prepare designs would be spent, so that if (and only if) dam levels fell below 30%, the additional expenditure would be committed. This option allowed sufficient time to build the plant before reaching dead storage. Effectively, this option acted like an insurance policy. As indicated earlier, however, the readiness option was overturned due to political intervention and the full USD 1,360 M (AUD 1,890 M) was invested.

The major water recycling projects developed were in response to the Metropolitan Water Plan 2006 commitment to reusing 56,750 AF/a (70 GL/a). Where economically viable to do so, SWC implemented wastewater recycling projects to assist in achieving this target. The projects included the Rouse Hill residential effluent reuse (third pipe, or dual reticulation) scheme, which was initially completed in 2001 and then extended in 2008 (currently supplying 19,000 homes), the Wollongong Recycled Water Scheme for industry and irrigation end users, and the Rosehill-Camellia Recycled Water Scheme in Western Sydney, also for industry and irrigation. Many smaller recycling schemes were also implemented across Sydney during this time by multiple public and private organisations in response to available government funding.

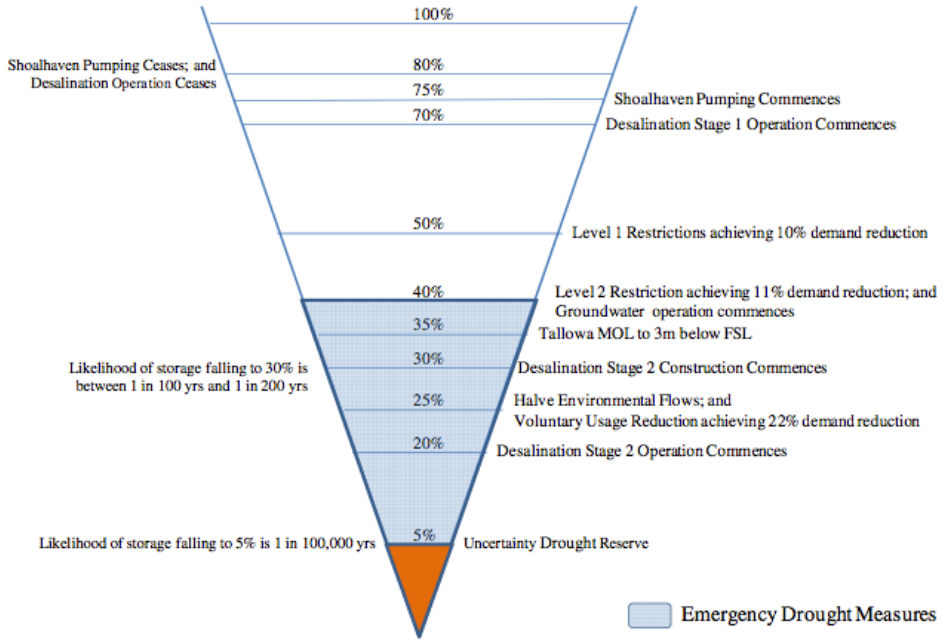
The costs of key supply options implemented are summarized in Table 4.2.

Table 4.2 – Key supply initiatives implemented by SWC (PC 2011)

Infrastructure	Capital Cost AUD	Capital Cost USD	Annual Yield ML/a	Annual Yield AF/a	Completed
Kurnell desalination plant	1,890 M	1,360 M	90,000 ML/a	72,960 AF/a	2010
Wollongong water recycling plant	25 M	18 M	7,300 ML/a	5,920 AF/a	2006
Rouse Hill Water Recycling Scheme (extension)	60 M	43 M	4,700 ML/a	3,810 AF/a	2008
Rosehill-Camellia Recycled Water Scheme	100 M	72 M	4,000 ML/a	3,240 AF/a	2011

New trigger levels specified in the 2010 Metropolitan Water Plan identify the trigger level at which the desalination plant should be switched on, how long it should run, and when the second stage 72,960 AF/a (90 GL/a) desalination plant capacity might be needed in relation to other demand- and supply-side options (SKM 2011 p.10). These trigger levels, shown in Figure 4.7, are under review in the 2015/16 Metropolitan Water Plan.

Figure 4.7 – Trigger levels identified in the 2010 Metropolitan Water Plan (source: MWD 2010)



The aftermath

With the rains and subsequent severe flooding in Sydney in 2012, the drought officially ended. Since then, and due to major investment in a broad portfolio of demand- and supply-side options, the activity in water planning and management has reduced significantly and the focus has changed.

Currently (2015/16) the Metropolitan Water Plan is being reviewed with a new focus on both potential flood risk to communities in the flood plain below Warragamba Dam, and revised drought triggers. This is in response to the risk of more frequent weather extremes, both droughts and floods, in Sydney and Australia more broadly.

In 2015 the SWC operating license was reviewed for the first time since the 2011 demand management target was achieved. The existing prescriptive demand management target has been retained in the new operating license, but a less prescriptive path has been identified for SWC, which will now be required to develop a methodology to determine the economic level of water conservation.

Since the end of the drought, government departments, which had previously focused on water demand management, have turned their attention to energy efficiency programs. This has been triggered by an attempt to reduce greenhouse gas emissions and to reduce the cost burden that customers are facing due to increasing energy prices associated with major investments in electricity supply infrastructure. Many of these programs have used the replacement of showerheads as part of a suite of measures designed to reduce energy use due to the well documented energy–water nexus savings that can be attained from reducing hot water use.

Meanwhile, water demand management teams have been downscaled, from over 80 staff in the prime of the program in SWC to a handful, with staff being absorbed into other parts of the business or laid off. Water demand management programs have come to an end or they have been scaled back to a minimum, with participant rates now often in the hundreds as opposed to the tens of thousands during the drought. Many of the programs in place now utilize cost recovery mechanisms. For example, the customer pays the full cost of a program and SWC acts more like a reliable ‘go to’ plumber service, whereas during the drought generous incentives were provided for rebates and audits to encourage customers to participate.

The price of water has increased significantly due to major schemes such as the desalination plant and relatively expensive reuse initiatives, some of which have had to reduce their

operations because customers no longer see the benefit of using recycled water, in part because restrictions have been lifted, or they have ceased business operations (ISF 2013).

Due to the burden of the cost of the unused desalination plant, the government has sought to refinance the plant in a sale to private investors[25], for USD 1.7 B (AUD 2.3 B) on a 50-year lease. In shutdown mode, it costs SWC customers over USD 0.36 M/day (AUD 0.5 M/day) in 'availability charges'.[26] The investors are guaranteed an inflation-linked payment of about USD 7.2 B (AUD 10 B) from SWC whether the water is used or not. Additional fees are payable to investors when the plant is switched on (Turner et al. 2013).

Lessons

Crisis and opportunity

In Sydney, the drought presented the opportunity and the need to rapidly expand demand management programs to achieve water savings. This was achieved by a combination of factors including: the policy and regulatory impetus created by the water efficiency target in the operating license; SWC's approach to detailed end use analysis to identify potential savings; the piloting of programs and subsequent evaluation which provided information about how much water programs could save; and integrated resource planning analysis to identify the relative cost-effectiveness of options.

The government also adopted some aspects of the best practice 'readiness strategy' for drought response, in terms of scheduling and staging options according to dam trigger levels. However, politicized 'crisis-mode' decision-making meant that the readiness strategy was not enacted – in particular, the desalination plant (which was subsequently not used) was built before agreed readiness trigger points were reached.

During the drought, reuse targets were established, and these targets drove investments in recycling. Restrictions on potable water uses – both experienced, and anticipated for future droughts – also spurred government, industry and local government interest in recycling. However, reuse had a different 'value' when the drought eased, resulting in some customers deciding to revert to potable water when able to do so after restrictions were lifted.

Working together

Transparency of decision-making is crucial during drought to engender trust by community and stakeholders. SWC's use of annual reporting of demand management programs provided a clear and transparent system to assess the impact of demand management compared to other water portfolio options. SWC's approach to evaluating programs to ascertain savings post-implementation, and its inclusion of these evaluations in the reporting processes, provided evidence that led other jurisdictions to adopt similar programs.

Getting the rules right

The use of 'no regrets' demand management programs in combination with national (WELS) and state (BASIX) regulations assisted in locking in savings and minimizing bounce back after restrictions were lifted. The experience of Sydney showed that BASIX-style regulations are particularly effective in contexts where demand is being driven by population growth.

As outlined above, water efficiency targets in SWC's operating license provided the regulatory impetus for successful investment in cost-effective demand management. However, following the drought, it was argued that prescribing the 'level' of water efficiency does not per se result in economically efficient outcomes, and that much water efficiency has already been achieved. Consequently, this specific target is in future likely to be replaced with the requirement to determine the economic level of conservation. While many water efficiency initiatives achieve long-term savings through one-off structural changes, others rely on ongoing efforts to reinforce behavior change or maintain savings through management practices. The removal of the target, combined with cutting demand management programs and staff, runs the risk of undermining millions of dollars of investment in demand management knowledge and savings which are required as part of the Metropolitan Water Plan portfolio.

[25] http://sydneydesal.com.au/about-sdp/ownership-structure
[26] http://www.abc.net.au/news/2013-09-27/nsw-desalination-plant-deal-costing-customers-10-billion/4985168

Picking the low hanging fruit

Investment in water efficiency programs in Sydney illustrates the magnitude of water savings that can be achieved at relatively low cost – the 'no regrets' options. The supply-side story illustrates the potential for best-practice decision-making, where real options analysis and 'readiness' strategies are considered in drought management together with careful consideration of hold and review points for major infrastructure, to limit unnecessary pre-emptive expenditure. However, as indicated above, this potential was not realized. It has been acknowledged that if the call to tender for the design, construction and operation of the desalination plant had been split with hold and review points, the 'readiness' strategy could have been preserved without the full cost of the pre-emptive build. In addition, not signing the full contract for the construction of the plant when the dam levels were at 57% would have avoided over-commitment (PC 2011; Giurco et al. 2014). Care is also required when refinancing desalination plants as this will cost customers even more in the long run and could cause delays in using them as part of a drought response strategy.

4.2 BRISBANE AND SOUTH EAST QUEENSLAND

Queensland is the second-largest state in Australia, covering an area of 71,500 square miles (1,852,642 km^2). It has diverse climates ranging from tropical in the north to subtropical in the south east and desert in the south west. The rapidly growing population, which increased from 3.7 million[27] in 2001 to 4.3 million[28] in 2011, predominantly resides in Brisbane, the capital city, and the surrounding 8,300 square-mile (21,544 km^2) South East Queensland (SEQ) region. In 2001 the SEQ population was 2.49 million. By 2011 it had grown to 3.18 million.[29] The region of South East Queensland includes the cosmopolitan city of Brisbane with an industrial center, the high-rise beachfront hotels of the Gold Coast and larger more rural style properties found to the west. These regions have vastly different water demands. SEQ was originally a collection of over 17 local councils, however these were consolidated to eleven in 2008 as part of the process of simplifying governance arrangements.

Prior to the drought, SEQ was heavily reliant on large dams, including the largest dam, Wivenhoe (944,500 AF or 1,165 GL) and several smaller dams including Somerset, North Pine, and Hinze, providing a further 612,900 AF (756 GL), with only limited interconnections between systems. Indeed, SEQ has the largest dam capacity to usage ratio of the main capital cities in Australia, reported as 6 times annual usage (ATSE 2012; PC 2011, p.19). Nevertheless, by the mid-2000s SEQ faced the prospect of severe water shortages due to the worst drought on record.

The Millennium Drought, which officially commenced in SEQ in 2001 and ended in 2009, dramatically altered the governance structures for supplying water, the supply system itself, attitudes towards water usage, and the demand for water.

Water planning

In 2003, in response to rapid growth in the region, the Queensland Government began to assess long-term water supply needs for SEQ over a 50-year period (Turner et al. 2007). As part of this process, numerous investigations were conducted over a number of years. These included studies into water demand, water demand forecasting, dam yields, and options to fill the anticipated future water supply–demand gap. As the drought intensified, the bulk, or wholesale, water authority (Seqwater) and local councils worked together to develop a short-term drought response strategy that included water restrictions, communication campaigns, and non-residential programs, incorporating audits, plans and retrofits.

In 2006, emergency legislation was passed (the Water Amendment Regulation No.6) to introduce a number of the drought response measures contained within the drought strategy. That same year, the Queensland Water Commission was established as an independent statutory authority responsible for achieving safe, secure, and sustainable water supplies for the SEQ region. The role of the Commission was to work with government departments, agencies, and local government water authorities to develop long-term water supply strategies, establish a water grid, manage demand, partly by implementing restrictions, and provide advice to government on water industry reform.[30] The Commission used a combination of demand-side measures and large-scale supply-side measures (such as new dams, a water grid, the Western Corridor Recycled Water Project, and desalination plants) to counter the worst effects of the drought.

Water demand

Prior to the drought and despite relatively good rainfall (mean 45 inches or 1,135 mm)[31], SEQ residential demand was typically high, at around 80 gpcd (300 lcd). While climate plays a role in above-average demand due to high temperatures in the region, there was also a contribution from Queensland's slow uptake of water pricing reform relative to other states.

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[28] http://www.abs.gov.au/ausstats/abs@.nsf/mf/3311.3
[29] http://www.abs.gov.au/websitedbs/censushome.nsf/home/qld-36?opendocument&navpos=620
[30] http://web.archive.org/web/20110110051732/http://www.qwc.qld.gov.au/about/index.html
[31] http://hardenup.org/umbraco/customContent/media/339_regionsummary-seq.pdf

As the drought wore on and short-term and long-term planning strategies were developed, it was recognized that consistent systems and processes were needed. Once defined, these were rolled out across SEQ to measure and forecast demand and assess options using more consistent end use- and sector-based methods.

This, in combination with implementing demand-side measures, including increasingly stringent restrictions and improved water efficiency based on a combination of instruments (regulatory, economic, and educative) across multiple sectors helped to dramatically reduce water demand. Figure 4.8 shows the residential, non-residential, and non-revenue water use between 2001 and 2010 in liters/capita/day (1 liter = 0.26 gallons). Figure 4.9 shows the demand for the residential sector against average rainfall in Brisbane for the period 2001 to 2014 and the levels of restrictions imposed. As can be seen, there has been limited bounce back in consumption after the drought ended in 2008, even after the severe floods of 2010/2011. Current residential demand is less than 45 gpcd (170 lcd).

Figure 4.8 – Historical water use by sector (note 300 lcd = 80 gpcd) (QWC 2010 p. 62)

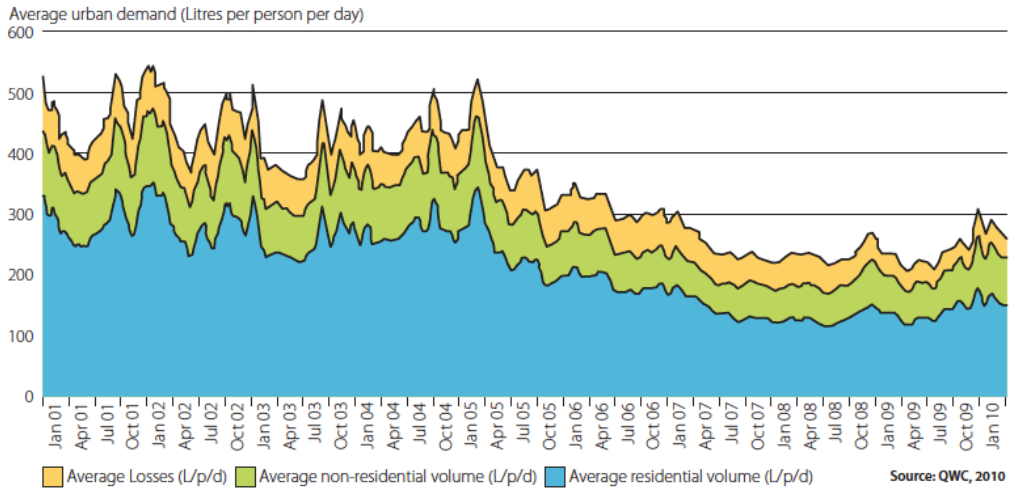
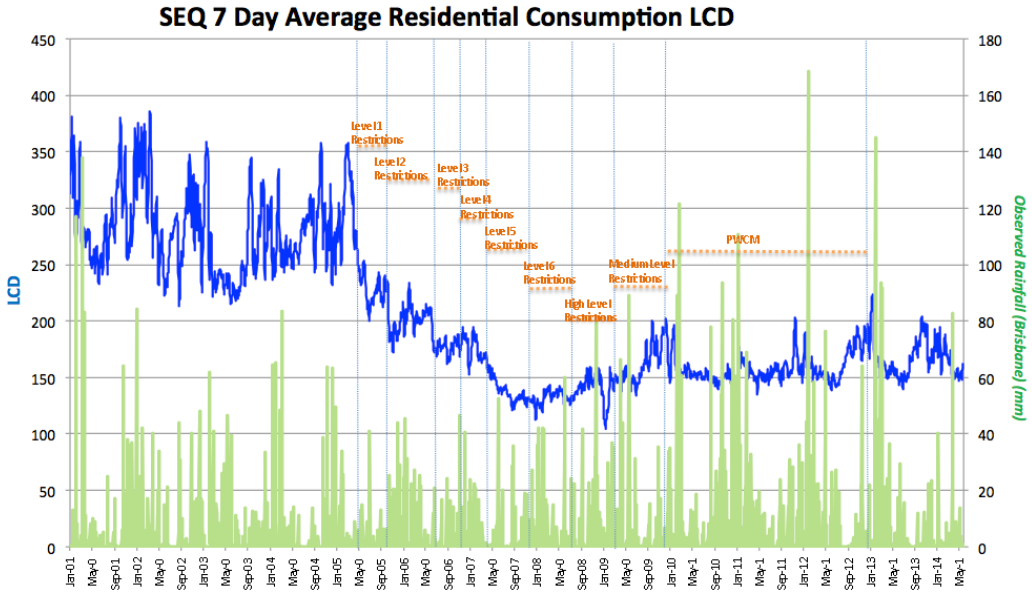


Figure 4.9 – Historical residential water use in Brisbane versus rainfall (note 200 lcd = 53 gpcd)



Demand side

In 2006/07 SEQ received record low rainfall (4% of annual average inflows) and faced the threat that dams could fall to less than 10% of their capacity before planned new water infrastructure identified in the drought strategy was completed. Hence, a comprehensive and innovative demand management program was used as a critical measure to slow the depletion of water levels in the dams, in much the same way as was done in Sydney, to buy time for decision-making and construction of new supplies. The main difference between SEQ and Sydney was that while Queensland had been active in water efficiency for many years with the WaterWise programs (first introduced in the mid-1990s), these programs were primarily focused on communication and therefore had a more limited impact on structural water efficiency.

The SEQ demand management program during the Millennium Drought used a combination of restrictions and innovative water efficiency programs which employed world leading approaches to marketing and communication. SEQ accomplished a highly successful large-scale rapid deployment of its demand management program. The program halved average residential demand in less than three years, with little subsequent bounce back. It did so with a combination of long-term structural and behavioral changes in a broad spectrum of sectors and by using advanced behavior change methods. The comprehensive program set a new standard in terms of speed and size of implementation and it employed a mix of initiatives.

The highly successful programs that were introduced at this time included the Home WaterWise Service, the High Water Users program and the One to One program. The Home WaterWise Service, introduced in 2006, was based on the Sydney WaterFix residential retrofit program. In SEQ a plumber fitted efficient showerheads and tap aerators, fixed minor leaks, and provided efficiency advice to householders. The advice included how they could access rebates for water efficient equipment under the USD 171 M (AUD 238 M) Home WaterWise Rebate Scheme introduced at the same time. A quarter of SEQ homes took part in the service in only two years. The High Water Users and One to One programs were introduced as more severe Level 5 restrictions were implemented. These highly innovative programs were linked to the Target 140 Campaign, which encouraged householders to limit their use to 37 gpcd (140 lcd) by changing water use behavior and taking up rebate offers. These programs focused on the top 10% of residential high water users – those using over 211 gallons (800 liters) per household per day. Over 80,000 households were contacted and after they responded to a survey they were given personalized plans to help them save water, again linked to the Home WaterWise Rebate Scheme to encourage both behavioral and structural changes within the home. Over 70,000 Water Savings Plans were delivered to customers. Table 4.3 provides summary details of some of the key initiatives.

Table 4.3 – Summary of key demand management initiatives

Initiatives	Summary details	Estimated costs, uptake and savings
Restrictions	As dam levels fell from 40% to 20%, restrictions were gradually tightened from Level 1 in May 2005 generally restricting residential outdoor watering times, to Level 5 in April 2007, significantly restricting residential outdoor water use including buckets only, vehicle spot cleaning, restrictions on pool filling/top-up and the introduction of Target 140 and the High Water Users program (see below). The non-residential sector was also subject to restrictions, including the introduction of Water Efficiency Management Plans, see below. Non-residential use was further tightened as part of Level 6* restrictions. Restrictions across SEQ were lifted after the drought ended in 2009. Permanent water conservation measures were then in place until the Queensland Water Commission was abolished in 2013.[32]	

[32] https://www.dews.qld.gov.au/policies-initiatives/water-sector-reform/queensland-water-commission

Initiatives	Summary details	Estimated costs, uptake and savings
Residential programs		
Home WaterWise Rebate Scheme[33,34]	This statewide program was introduced in mid-2006 and provided rebates for showerheads, dual-flush toilets, washing machines, garden products, pool covers/rollers, greywater systems and rainwater tanks. The vast majority of rebates were for washing machines and rainwater tanks (by mid-2008 >188,000 washing machines and >239,000 rainwater tanks). The program ended in late 2008.	Statewide >AUD 280 M USD 201 M >465,000 rebates
Home WaterWise Service	This program was introduced in 2006 in 21 SEQ councils (in 2008 consolidated to 11 councils) and was designed and implemented by Local Government Infrastructure Services. Under this program, a licensed plumber visited the home, provided advice, installed efficient showerheads and tap aerators, and fixed minor leaks. The program, which was linked to the rebate scheme, was implemented on 228,500 households[35] in two years, around a quarter of homes, greatly exceeding the target of 150,000 households within 18 months (Coates and Bullock, 2008).	AUD 43 M USD 31 M 228,500 households
Target 140*	This was a massive communication campaign introduced with Level 5 restrictions in April 2007 that was based on behavior change principles. It was linked to other components of the demand management program and sought to reduce SEQ water use by 10% by the end of 2007, and encourage residents to use 37 gpcd (140 liters/capita/day) by August 2007. The highly inclusive and motivating campaign used: extensive media coverage with strong messaging, imagery and celebrities; a direct mailout of 4-minute shower timers, refrigerator magnets and information booklets; a website; fact sheets and posters; and stakeholder partnerships, with local councils and celebrities.	AUD 4.2 M USD 3 M
High Water Users and One to One water saving program (Turner et al. 2010)	These programs were initiated in combination with Level 5 restrictions and the Target 140 (liters/capita/day) campaign. They involved identifying high water-using households (>210 gallons/household/day or 800 liters/household/day), and providing a survey form of >50 questions to 80,000 households to find out why these households were using so much water. The survey received a 92% response rate. It subsequently provided a follow-up personalized Water Savings Plan to those households using >37 gpcd (140 liters/capita/day) to advise on how to save water (linked to the rebate scheme). The High Water Users Program was a water restriction	70,000 households

[33] http://statements.qld.gov.au/Statement/Id/59876
[34] http://staging.renovate.com.au/docs/index.cfm?page=print&record=854
[35] http://www.lgis.com.au/web/lgis-redundant/case-studies/-/asset_publisher/Qt1e/content/home-waterwise-service

Initiatives	Summary details	Estimated costs, uptake and savings
	requirement that could result in an infringement or installation of a flow restriction device if the occupier could not advise why the consumption was at that level (e.g. number of people, home business, medical condition). The One to One Program was a voluntary program.	
Non-residential programs		
Water at Work campaign	This program encouraged and supported SEQ residents to take water saving behavior to their places of work by, for example, turning off taps when not in use, running dishwashers full, taking 4-minute showers, and reporting leaks. It also introduced workplace water efficiency audits.	
Business Water Efficiency Program and rebates/subsidies	Businesses using >0.8 AF/a (1 ML/a), in a combination of enforcement and rebates, were required to have water efficient devices, such as water efficient taps, showerheads and trigger sprays. The rebate program operated in conjunction with the restriction requirements. A selection of businesses received a rebate, including support for development of WEMPs (see below) and major process changes to deliver significant water savings.	AUD 3 M USD 2.2 M > 2000 applications
Water Efficiency Management Plans (WEMPs)[36]	The program targeted businesses using > 8 AF/a (10 ML/a) and nurseries, public swimming pools, buildings with cooling towers, and areas using potable water to irrigate areas > 5,400 square feet (> 500 m^2) were required to develop plans to demonstrate 25% reductions in water use or best practice.[37]	
Industry communication and stakeholder engagement	This campaign focused on helping particular sectors, such as sporting bodies responsible for large grassed sports playing fields, mobile commercial washers (i.e. dog washing operators), and visitor accommodation providers with tips, fact sheets, and education materials. Stakeholder groups were formed and enforceable guidelines were developed. These became part of the water restrictions program. Training programs were developed including compliance for car wash facilities (mobile and fixed), dog wash facilities (mobile and fixed – e.g. vets), house washers, and managers of active recreation areas (sporting fields).	
System		
Pressure and leakage management*	State government regulation involving 18 councils.	AUD 90 M USD 65 M 60 ML/day 49 AF/day

[36] http://www.qldwater.com.au/WEMPs
[37] https://www.dews.qld.gov.au/policies-initiatives/water-sector-reform/queensland-water-commission

In addition to the demand management program, regulations played a significant role during the 7-year drought in SEQ, due in part to the significant growth in the region. Regulations such as the national level Water Efficiency Labeling Scheme and local building regulations[38] introduced in 2006/07 required every new detached and semi-detached house in Queensland to be fitted with a rainwater tank, a wastewater reuse system or stormwater reuse system to reduce water demand on reticulated town water supply systems, in addition to water saving fixtures such as water efficient taps and shower heads. These regulations were modified on several occasions, including specifying a range of targets for water demand reductions ranging from 2,650 to 18,500 gallons/property/a (10 to 70 kl/property/a) depending on geographical location.[39] Rainwater tanks were predominantly used to achieve such targets, driving rainwater tank installation growth in SEQ. This mandatory requirement was repealed in 2013[40] by the Queensland Commission Authority due mainly to concerns over the economic viability of rainwater tanks as a water source.

Supply side

In addition to demand-side measures, there were significant changes made to the water infrastructure system. These changes included: new water supply sources, linkages through a water grid system, construction of the first major desalination plant in SEQ, and the construction of the Western Corridor Recycled Water Scheme, one of the largest recycled water schemes in the world. These schemes, listed below in Table 4.4, cost more than USD 4,320 M (AUD 6,000 M). The large proposed Traveston Crossing Dam, over 100 km (62 miles) north of Brisbane, was at one point included within the drought strategy investigations (>USD 1800 or AUD 2,500 M for stage 1 including delivery network, based on 2006 costs) until the development of the dam was eventually refused by the federal government on the grounds of listed threatened species and community opposition.

Table 4.4 – Summary of key supply initiatives

Infrastructure	Capital cost AUD	Capital cost USD	Annual yield Ml/a	Annual yield AF/a	Year completed
Desalination (Tugun, Gold Coast)	AUD 970 M	USD 700 M	48,545 Ml/a	40,000 AF/a	2009
Western Corridor (Purified Recycled Water Plant)	AUD 1200 M	USD 865 M	84,680 Ml/a	70,000 AF/a	2008
PRW pipelines	AUD 1149 M	USD 825 M			
Northern Pipeline	AUD 829 M	USD 595 M			
Southern Pipeline	AUD 855 M	USD 615 M			
Eastern Pipeline	AUD 39 M	USD 28 M			
Hinze Dam Raising (additional	AUD 454M	USD 325 M	149,657 Ml	121,300 AF	

[38] such as the Queensland Development Code (part 25) introduced in 2006/07
[39] http://www.hpw.qld.gov.au/SiteCollectionDocuments/SP%204.2%20Water%20savings%20targets%20-%205%20December%202006%20(previously%20part%2025).pdf
[40] http://www.hpw.qld.gov.au/SiteCollectionDocuments/BuildingAndPlumbingNewsflash513.pdf

volume)				
Wyaralong Dam	AUD 379M	USD 275 M	Full volume 102,883 Ml	83,400 AF
Bromelton Off Stream Storage	AUD 73M	USD 55 M	Full volume 7,338 Ml	5,950 AF
Cedar Grove Weir			Full volume 1,144 ML	930 AF

Aftermath

The dams reached their lowest levels (17%) in 2007 before the drought officially broke in 2008. At that time further major reform included the reconfiguration of the water supply industry. Also in 2010 the Queensland Water Corporation released the SEQ Water Strategy to lay out a water security plan for the SEQ region for the next 40 years. This plan was linked to various other regional plans, all of which are reviewed every 5 years or as circumstances change. The reviews consider, for example, water availability, water demand, service levels, potential effects of climate change, triggers for drought response, and potential options available to fill the supply–demand gap (QWC 2010).

Soon after the release of these plans, severe flooding occurred in the SEQ region at the end of 2010–early 2011 with loss of life and billions of dollars of damage. This illustrates the extremes of climate including severe drought and severe flooding. Due to the major floods, subsequent rains and reductions in water demand, water levels of the combined regional dams have remained in excess of 80% since 2010.[41] As a result, some of the major new supplies that were developed during the drought are not being used or have limited use. The Western Corridor Recycled Water Scheme has been shut down until water shortage issues return. The Tugun desalination plant has not been used for base supply, but has been used for back-up when other supplies are offline for maintenance or due to contamination.

Another iconic scheme, Pimpama Coomera, which uses recycled water for toilet flushing and outdoor uses, is scheduled for closure due to its high operating costs.[42] In addition, the mandatory requirement for alternative sources in new houses to reduce demand was repealed in 2013[43] after cost-benefit analysis found that these systems were not cost effective. However, councils can opt into the requirement if they choose to do so. After two years of operation, the functions of one of the water distribution and retailing entities passed back to the three separate local councils and after six years the Queensland Water Commission ceased operation. Policy and regulatory functions moved to the Queensland Department of Energy and Water Supply and water security functions became the responsibility of Seqwater (the bulk supply authority).

Key lessons

Crisis and opportunity

The establishment of the Queensland Water Commission was a good example of rapid institutional water reform during drought. Establishing an agency with overarching policy, planning, and regulatory functions enabled coordination of water use information, strategy development and implementation across formerly fragmented water supply services managed by individual councils. A key advantage of this was consistency of both the message and the rules associated with water restrictions across a number of council water authorities. For the community, having one voice to listen to meant that the message was much easier to hear and absorb.

Working together

SEQ's successful, and especially rapid implementation of water efficiency programs during the drought was in part facilitated by drawing on lessons and building on the water efficiency

[41] http://www.Seqwater.com.au/water-supply/dam-levels
[42] http://www.goldcoast.qld.gov.au/environment/pimpama-coomera-waterfuture-residents-and-businesses-7904.html
[43] http://www.hpw.qld.gov.au/SiteCollectionDocuments/BuildingAndPlumbingNewsflash513.pdf

program experiences of other cities, including Sydney and Melbourne, which were also experiencing serious drought at the time. In other cases, the experience of SEQ was extremely useful for supporting other cities to implement programs. This illustrates the value for those organisations that are charged with implementing water efficiency programs of working together to learn from and build on practice and implementation expertise from elsewhere in the water industry.

The Target 140 and One to One programs were highly innovative and successful, with the Target 140 programing later adopted by Melbourne as Target 155. This further demonstrated the sharing of ideas and approaches between water utilities and agencies across the country. This was often facilitated through national industry bodies such as the Water Services Association of Australia, Australian Water Association, and National Water Commission networks, conferences and workshops.

The other feature was stakeholder engagement. The responsible agency did significant market research, as well as extensive discussions with industry associations to increase the success of the programs.

Speaking and listening

A water efficiency strategy comprises many different elements, and the success of the multi-faceted program in SEQ illustrated the importance of integrating the different elements – communication, promotion, and behavior change as well as programs that provided long term efficiency gains by changing fixture and appliances. This enabled programmatic as well as cross-promotional links, such as linking the 'educative' elements of the high water users' program to the 'structural' element of retrofits.

Getting the rules right

In SEQ, regulations were introduced to require new developments to incorporate water efficient equipment and reduce demand through rainwater tank use and recycled water. However, some aspects of these requirements within development regulations were later repealed as a means of 'reducing red tape', illustrating the difficulty of maintaining consistency between long-term supply–demand planning and drought response planning.

Picking the low hanging fruit

SEQ applied a broad portfolio approach to identifying potential options that assisted in moving away from rain-dependent sources and subsequently implemented significant demand-side and supply-side initiatives. In terms of water efficiency, residential programs such as Target 140 and the high water users' program were highly successful. Similarly, the Western Corridor Recycling project was a good example of a contingency option, which was established in a way that could have been used for indirect potable reuse, replenishing the main water supply dam, had the drought continued.

4.3 PERTH, WESTERN AUSTRALIA

Perth and the water supply system

The city of Perth, with a current population of nearly 2 million, is the capital of the state of Western Australia (WA), which covers the entire western third of Australia, an area of 1 million square miles (2.6 million km^2). Three-quarters of the state's population resides in Perth.

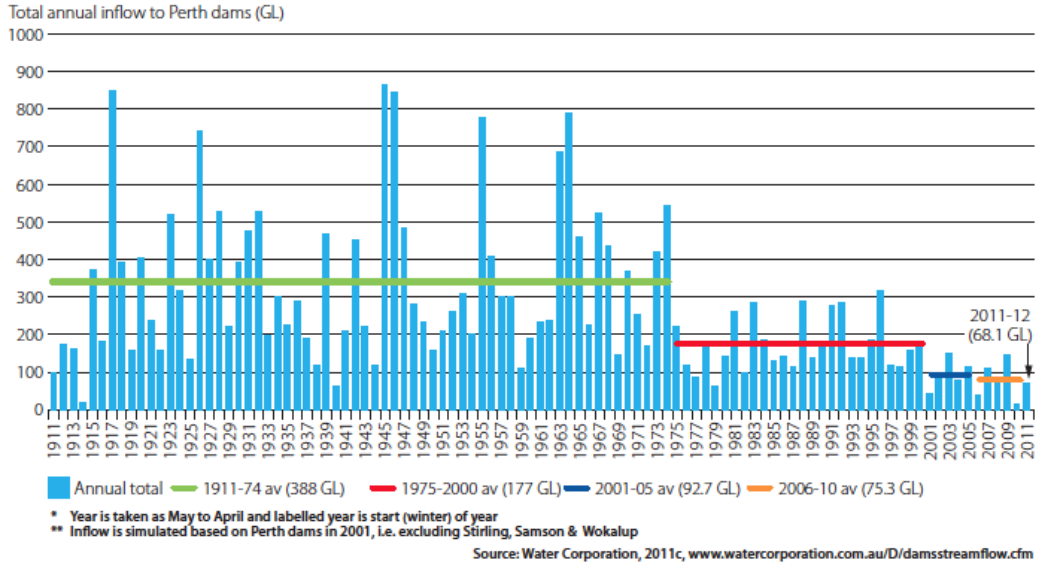
In 2001, when the population was 1.4 million, Perth witnessed a step change, a sudden and significant decrease in inflows to dams. By 2011, the population had risen to 1.7 million and there was another downward step change in inflows. By this time the drought had broken in other parts of the country.[44]

Perth has a Mediterranean climate, similar to much of California, characterized by hot dry summers and cool wet winters. The current average rainfall is 33 inches (840 mm). Rainfall has been steadily declining over the last century, with a decline of over 30% since the early 1900s observed in the southern Jarrahdale dam catchment area.[45]

Reduced rainfall has had a significant impact on stream flows, as well as surface and groundwater reserves. A 12% decline in rainfall since 1990 has resulted in a dramatic 50% reduction in stream flows into Perth's dams (WCWA 2013, p.3). The significant decline in inflows over the last 40 years, commencing in the mid-1970s, is shown in Figure 4.10.

Figure 4.10 – Annual inflows to Perth dams (ATSE 2012)

Note: 1 megaliter = 0.8 acre-feet



Perth is linked to a complex water system, covering a large area which includes agricultural regions. This system is managed by the Water Corporation of Western Australia (WCWA), a publicly-owned water utility established in 1996, which provides 97% of water and wastewater services in WA (ERA 2004, p.15).

Perth has access to water from both dams and groundwater reserves, unlike other major Australian cities. Over time, groundwater has been used to provide a significant proportion of annual water supply. Groundwater is also used directly by farmers, industry, and households; indeed, the amount of groundwater used by these private water uses exceeds that extracted for public water use supplied by the WCWA (for residential, business as well as the Goldfields and Agricultural regions). In 2001, public water use was drawn predominantly from groundwater sources as surface water sources were becoming less reliable (WCWA 2009, p.16).

[44] http://blog.id.com.au/2012/population/australian-population/perths-population-a-story-of-economic-boom/
[45] http://www.watercorporation.com.au/water-supply-and-services/rainfall-and-dams/rainfall

Perth's surface water supplies experienced major reductions in inflows. As a result, there was a strong need to further explore water efficiency and sources which were not rain-dependent, including additional groundwater sources, desalination, and recycling. Due to the potential environmental and social impacts of these sources, assessing the feasibility, costs, and impacts required extensive investigations. Hence, decision-makers in Perth and WA as a whole have a long history of water planning in consultation with the community.

Water planning

Over the last decade, WA has undertaken numerous water planning exercises with multiple stakeholders. In 2001, the WA Government held a water symposium to develop the *Securing Our Water Future: A State Water Strategy* involving both the government and community. Public forums were held regionally, and these assisted in the formulation of numerous recommendations, from water efficiency targets to new supplies to be delivered by multiple agencies. The WCWA targets and responsibilities included reducing water use to 40,000 gallons per person per annum (155 kl/person/a) for total water use by the metropolitan water users and achieving a 20% reuse target by 2012 (Government of WA 2003). This strategy was eventually finalized in 2003 (Government of WA 2003). Within the strategy, integrated resource planning principles were specifically articulated (refer to box).

The Strategy and associated water efficiency targets gave rise to the launch of the multi-million dollar statewide Waterwise Rebate Scheme in early 2003 (described below). In 2005, a committee was established to guide water reform in WA. As part of the State Water Plan released in 2007 a priority action was for the WCWA to engage with the community about water source options for the city and surrounds. In 2009, the *Options for Our Water Future Paper* considered options ranging from water efficiency measures, individual to community-scale alternative supplies, recycling (including groundwater replenishment), desalination, surface water, and groundwater.

> '*Integrated resource planning ensures that options that reduce demand on valuable water supplies are compared on an equal basis with options that increase supply. This is achieved by viewing water saved through water conservation as a resource, in exactly the same way water stored in a dam is regarded as a resource. Comparisons include the total costs and benefits to water service providers and the community, ensuring that the water planning options implemented are those with the lowest cost to the community.' (Government of WA 2003).*

Also in 2009, the WCWA produced *Water Forever: Towards Climate Resilience,* a 50-year plan to secure water supplies. This plan aims to reduce demand to 125 kl/person/a by 2030 (90 gpcd or 342 lcd) comprising 61 gpcd (85 kl/person/a) residential and 29 gpcd (40 kl/person/a) average for all business, industry and services.

By 2060 the plan aims to reduce demand to 110 kl/person/a (80 gpcd or 301 lcd) comprising 19,800 gallons per person per year (75 kl/person/a) residential and 9,240 gallons/ person/year (35 kl/person/a) business, industry and services (WCWA, 2009). In 2012 and 2013 the WCWA released additional plans to work towards the 50-year target, including further details on water recycling and water efficiency (WCWA 2013).

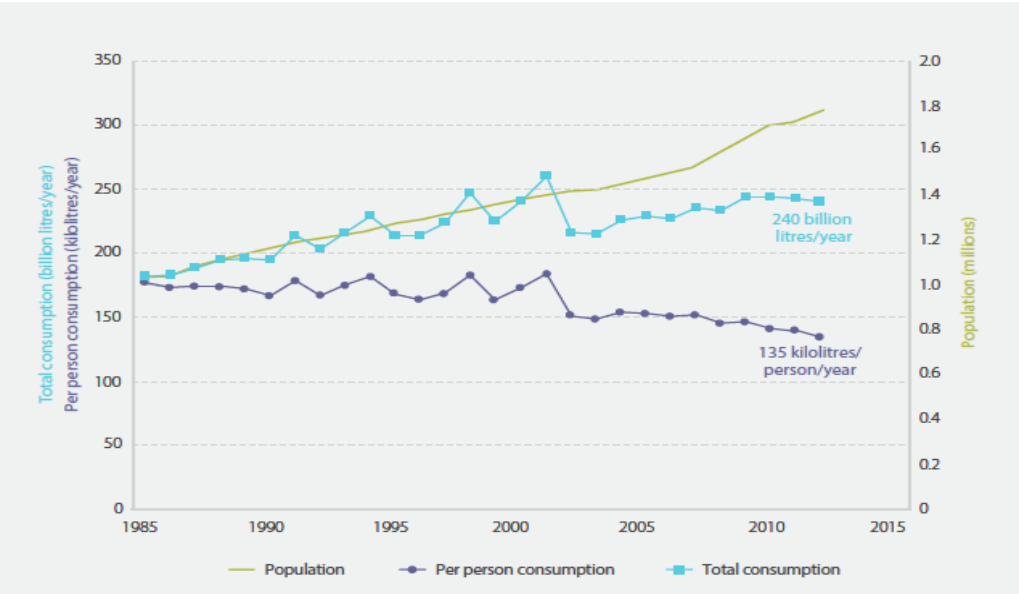
Water demand

Among the major cities in Australia, Perth has historically been one of the highest water users on a per capita basis (WCWA 2009, p. 35). Volume-based water pricing and water restrictions were introduced in the late 1970s, resulting in a dramatic drop in total water demand from a high of over 166 gpcd (630 lcd) to 90 gpcd (342 lcd) in the late 1970s (Turner et al. 2005). The water restrictions at that time caused significant concern in a community that, until that point, had used nearly three-quarters of the city's water on suburban gardens during the summer months. The backlash from the community about water restrictions meant that the state government was subsequently averse to using stringent restrictions. This was apparent in 2005 when the government renewed its commitment to reducing the likelihood of a total ban on water sprinklers to just one year in two hundred – a very conservative approach to restrictions compared to those adopted in other cities in Australia at that time (Morgan 2015).

From the early 1980s total water demand per person steadily rose again to an average of around 127 gpcd (479 lcd), until two-day-a-week sprinkler restrictions were introduced in

September 2001, which resulted in a decline in water use back to 110 gpcd (416 lcd) in 2001/02. By 2011/12 demand was 100 gpcd (135 kl/person/a) due to a combination of water restrictions and other demand-side measures. From 2001 demand generally remained below the 112 gpcd (155 kl/person/a) target. Refer to Figure 4.11.

Figure 4.11- Historical total and per person total water usage (source: WCWA 2013, p. 12). Note: 200 kiloliters per year = 53,000 gallons per year; 200 billion litres per year = 167,000 acre-feet per year.



Even with water demand falling in recent years, Perth consumers remain the highest water users per capita among the major cities in Australia (WCWA 2009, p.34). This is in part due to its Mediterranean climate, as well as its sandy soils, and the value residents put on living with large areas of turf. Actual water use is higher because a third of households are connected to a private household well (WCWA 2009, p. 9) for outdoor watering, which means this water demand is not reflected in reported potable water figures. These wells tap into the relatively shallow aquifers typically less than 160 feet (50m) deep. This indicates that even though significant demand-side measures discussed below have been implemented, there is still the potential for increased water efficiency for various indoor and outdoor end uses, as explored in the Perth Residential Water Use Study (WCWA 2009). The WCWA was the first major utility to undertake an end use study, measuring the disaggregated customer uses of water by appliance and fixture (Loh and Coghlan 2003), pioneering the use of evidence-based demand analysis. The study was conducted between 1998 and 2001, and has been replicated by other cities in Australia. These studies are used to understand household water demand and are useful for demand forecasting and options analysis using the principles of integrated resource planning.

Demand side

In 2001 when Perth faced a step change in inflows to dams, restrictions beyond Level 1 were implemented for the first time in over 20 years. Following the release of the 2003 State Water Strategy, a large-scale residential demand management program (the Waterwise Rebate Scheme) was launched to reduce the risk that Perth would need a total outdoor water use ban. Within just two years of the program's launch, 80,000 washing machine rebates were administered through the program, and by the end of the program in 2009, over 200,000 rebates were processed. This program helped to transform the washing machine market in Australia and to greatly increase the availability of efficient, predominantly front loading, washing machines (Turner et al. 2005; WCWA 2009, p. 37). The WCWA also led the way in developing strong industry linkages, training, and certification arrangements with plumbers, garden centers, and irrigation specialists. This was subsequently replicated by other utilities. Table 4.5 summarizes some of the key programs implemented.

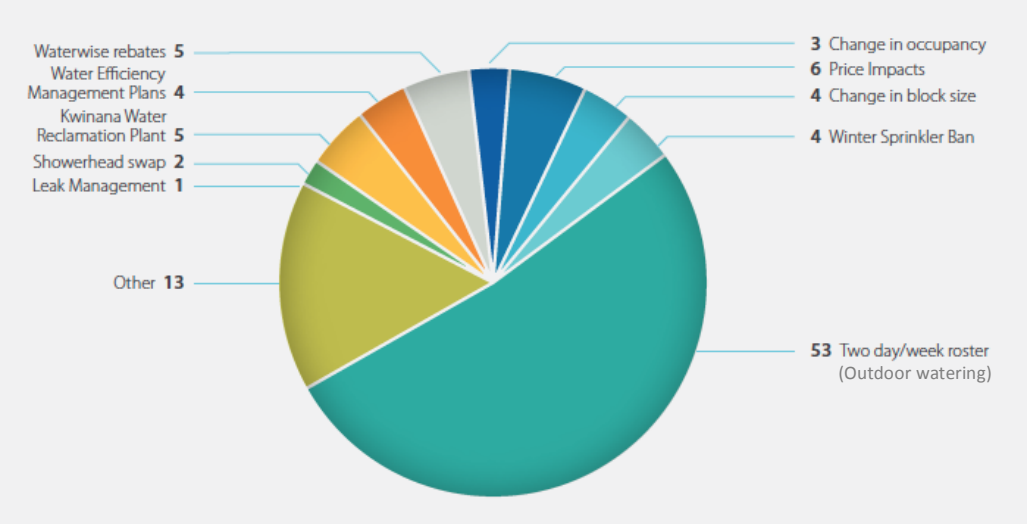
Table 4.5- Summary of initiatives

Initiatives	Summary details	Estimated costs, uptake and savings
Restrictions	Prior to 1994, restrictions were implemented in Perth in the late 1970s. Since 1994, there had been Stage 1 restrictions (a ban on sprinklers between 9 am and 6 pm) with high community support (WCWA 2009, pdf p.25). In 2001, due to the significantly reduced storage volumes and the intent to save 36,480 AF/a (45,000 ML/a) to prevent more severe restrictions (i.e. total sprinkler ban), Stage 4 restrictions were put in place (limiting sprinklers to two days/week) (Turner et al. 2005). Additional winter sprinkler restrictions and a temporary one-day-per-week watering roster were implemented in the spring of 2010.	
Residential Programs		
Waterwise Rebate Scheme	In early 2003 the state government released the program in response to the targets identified in the State Water Strategy. The Water Corporation administered the program on behalf of the state government from 2003 to 2009. The numbers in parentheses show the numbers of rebates provided: • indoor products – showerheads (22,944) and washing machines (210,826), flow regulators (207) • outdoor products – pool covers (29,476), garden irrigation systems (392), subsurface irrigation systems (8,263), rain sensors (813), tap timers (2,495), soil wetting agents (68,579) • alternative systems – garden bores (23,541), rainwater tanks (15,648), greywater systems (245), aerobic treatment units (112) as well as garden assessments (56).	Costs AUD 46.2M USD 33.2M Rebates granted >383,597 Estimated savings 5,000 ML/a 4,050 AF/a
Foundation program	As part of the Waterwise Rebate Scheme, an extensive multifaceted advertizing and awareness/communication campaign was implemented. In addition, due to significant outdoor water use, the WCWA initiated strong industry linkages and training and certification arrangements with plumbers, garden centers, and irrigation specialists.	
Showerhead swap	The program ran from 2011 to 2013. Participants could exchange up to two showerheads for free efficient models. The customer's most recent water bill was required. Showerheads could be exchanged at local hardware stores. Rental properties were also eligible to participate on the same terms.	Showerheads 124,000
Toilets to go	The WCWA partnered with the private sector to provide households and businesses with the chance to swap single-flush toilets for 4 star dual-flush toilets at a reduced cost. Participants had a choice of 3 toilets.	

Non-residential programs		
Water Efficiency Management Plans (WEMP)	The program commenced in 2007 and required all businesses and government agencies in WA using > 16 AF/a (20 ML/a) to conduct a water management assessment and submit annual water efficiency management plans to the WCWA on progress in reducing consumption (WCWA 2013, p. 10).	Estimated savings 3.8 ML/a 3 AF/a

According to published data the overall breakdown of savings from the program is as shown in Figure 4.12 with the vast majority of savings being attributed to water restrictions, namely the two days per week watering roster.

Figure 4.12- Savings breakdown (source: WCWA 2013)



Supply options

Several options were proposed to augment water supplies in the region, including:

- **Recycling** – The Kwinana Water Reclamation Plant supplies approximately 4,000 AF/a (5 Gl/a) non-potable water, equal to about 2% of Perth's current annual water use, predominantly to large industrial users near the wastewater recycling facility. Indirect potable reuse via groundwater replenishment[46], or aquifer recharge, has now also been shown to be a highly viable option to boost drinking water supplies in Western Australia, and is expected to provide an additional 12,000 AF/a (14 Gl/a) of water from 2016.
- **Desalination** – The first major desalination plant in Australia, the 36,500 AF/a (45,000 Ml/a) Kwinana desalination plant, was completed in 2006 and provided about 20% of total supply at that time. By 2012, another plant had been constructed to the south of Perth at Binningup, providing a total of 81,000 AF/a (100 GL/a) and bringing the total desalination supply in Perth up to 40%. Both plants remain operational.
- **Transfers** – Transferring water from the Kimberley[47], a wet region over 2,175 miles (3,500 km) north of Perth, via pipeline, canal or ocean transport. After lengthy analysis, these options were finally ruled out in 2005 because they were considered too costly.

[46] http://www.watercorporation.com.au/water-supply-and-services/ongoing-works/groundwater-replenishment-scheme
[47] https://www.water.wa.gov.au/__data/assets/pdf_file/0007/4966/64772.pdf

The cost, capacity and completion dates of recent large-scale supply-side initiatives are summarized in Table 4.6.

Table 4.6 – Large supply-side initiatives (PC 2011)

	Capital cost AUD	Capital cost USD	Yield ML/a	Yield AF/a	Year completed*
Kwinana Water Reclamation Plant	AUD 28M	USD 20	6,000 ML/a	4,865 AF/a	2004
Desalination (Kwinana)	AUD 387M	USD 280	45,000 ML/a	36,480 AF/a	2006
Desalination (Binningup) stage 1 and 2	AUD 1,400M	USD 1,010	100,000 ML/a	81,070 AF/a	2012

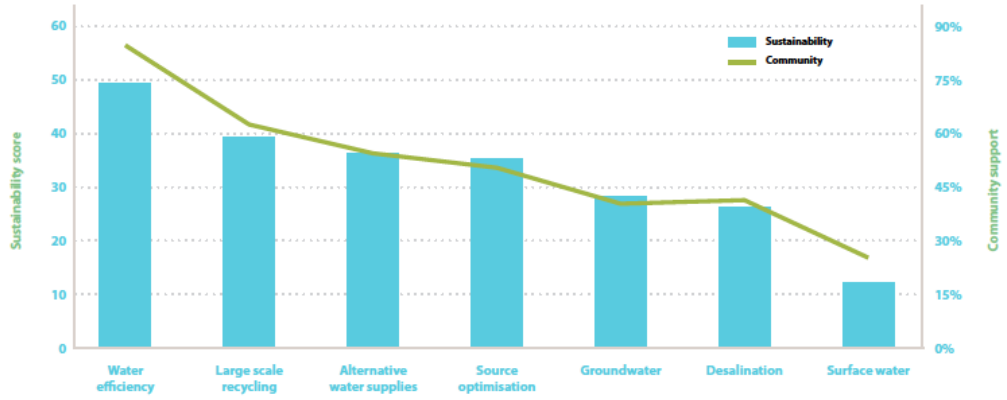
* Costs incurred at that time

Aftermath

In Perth, it has been widely assumed that what has been experienced is not a drought but rather a long-term shift in climate, a shift that may continue. As part of the *Water Forever: Towards Climate Resilience* 50-year plan released in 2009, a portfolio approach has been adopted. In 2001, the Perth system relied exclusively on groundwater and surface water supplies. Today, nearly 122,000 AF/a (150 Gl/a), representing 41% of demand, is supplied by desalinated seawater from the Kwinana and Binningup plants. An additional 42% comes from groundwater reserves and less than 17% from surface water dams. As Perth enters the summer of 2015/16 dam storages are below 30%, even though water has been transferred into the dam system from the desalination plants as part of a policy to “bank” desalinated water in the winter when demand is lower.

Over the next 50 years, water demand in Perth is expected to decline by 25% due to denser urban developments, which use less water, and the continuation of many of the existing water efficiency programs. In addition, there is a major focus on increasing water recycling, largely through groundwater replenishment, or aquifer recharge. Significant work has been done on trialing and transferring groundwater sources from higher aquifers within the complex groundwater system to deeper more reliable groundwater sources. There have also been investigations into increasing desalination to further offset declining inflows to dams (WCWA 2013). Figure 4.13 shows the community’s views on the ranking of these options (WCWA 2009) and the alignment of these views with sustainability indicators. Water efficiency and large-scale water recycling have the greatest support, while desalination and especially surface water have much less support.

Figure 4.13- Community views on future water sources compared to sustainability indicators (source: WCWA 2009)



Alternative water supplies refers to rainwater tanks, garden bores and community bores.
Source optimisation refers to catchment management, water trading, cloud seeding and reducing evaporation from dams.

Lessons

Crisis and opportunity

Perth's water supply system was confronted with the decline in inflows earlier than those in the east of Australia. This decline in inflows captured public attention, and, combined with strong community engagement by the state government and the WCWA, increased awareness within the community about water issues. The community engagement on the State Water Strategy indicated strong support for investment in water efficiency and recycling in WA as a means of meeting water needs.

As conditions worsened, policy-makers sought to "drought-proof" the system through the construction of desalination plants. This was also seen as a means of avoiding a complete ban on outdoor water use. More recently, there have been large-scale investments in recycled water to replenish groundwater. There is a real risk that the high level of capital expenditure for increasing water supply reduces efforts to pursue cost-effective water efficiency measures. It is important to ensure that investment in these options is not curtailed due to the reallocation of priorities once the sense of urgency has passed. There are profound cost implications for customers, and equity implications for low water users of a path of prioritizing higher unit cost supply options over lower unit cost water efficiency improvements.

Working together

The WCWA and the WA Government showed great leadership in establishing partnerships with industry on water saving initiatives. This is demonstrated by the long running outdoor water programs with the irrigation and garden industries.

The water industry in WA was also an early adopter of an evidence-based approach to understanding water usage, through its pioneering residential end-use study. Perth was one of the first major cities where this research, including household surveys, was undertaken. These studies have been replicated in other cities to inform the development of water demand forecasting models and associated options assessment models, allowing more accurate predictions of the role that water efficiency could play in both short- and long-term water planning and management.

Speaking and listening

Western Australia has a long history of comprehensive, high quality engagement processes involving the community in water planning. The WCWA and the WA Government have conducted numerous community consultation processes over the last decade. The outcomes of these processes, in particular the 2003 community engagement, indicated a strong preference for water efficiency, and a lower preference for desalination. There has been a very strong historical commitment to water saving measures in WA, and in particular the implementation of a permanent two day per week garden watering roster and associated behavior change measures have had a major impact on demand. However, the levels of investment in structural water efficiency measures have not reflected the potential savings available, the need for action,

or the high marginal cost of water. On a per capita basis, the investment levels in efficiency are well below those of Sydney and South East Queensland.

Getting the rules right

The WCWA was the first utility in Australia to implement a comprehensive, community-wide water efficiency program, based on the principles of integrated resource planning. This was the Kalgoorlie-Boulder Water Efficiency Program, implemented in 1995 at a cost of USD 100 (AUD 138) per person. Further to this, the 2003 State Water Conservation Strategy explicitly referred to the need for integrated resource planning.

Following a period of significant caution regarding the use of recycled water and non-potable sources, the Western Australian regulatory agencies have facilitated the largest trial of indirect potable reuse in the country, in the form of aquifer recharge from recycled wastewater. This is important for the Perth regional water supply and for reducing the strain on groundwater systems and for reducing the high operating and capital cost of desalination. It also provides an example for other Australian cities.

It is not clear, however, whether the current economic regulatory arrangements administered by the Economic Regulation Authority recognize the importance of investing in the lowest cost options, in particular, optimum levels of investment in water conservation measures, consistent with the high operating and capital costs of new supply. For example, the estimated long-run marginal cost of water supply is USD 5.60 to 11.40 per hundred cubic feet (AUD 1.49 to 3.11 per kiloliter in 2015/16) (ERA 2013). This is much higher than the unit cost of many water efficiency options.

Picking the low hanging fruit

Perth's planning is an example of how to use broad portfolio thinking to consider supply- and demand-side options. Much has been achieved through investment on the demand side, such as the large-scale washing machine rebate program that helped transform the washing machine market. It is recognized that there is still significant scope for further water savings, and that there is potential to tap into further opportunities for using recycled water, two key options favored by the community (WCWA 2009).

4.4 MELBOURNE, VICTORIA

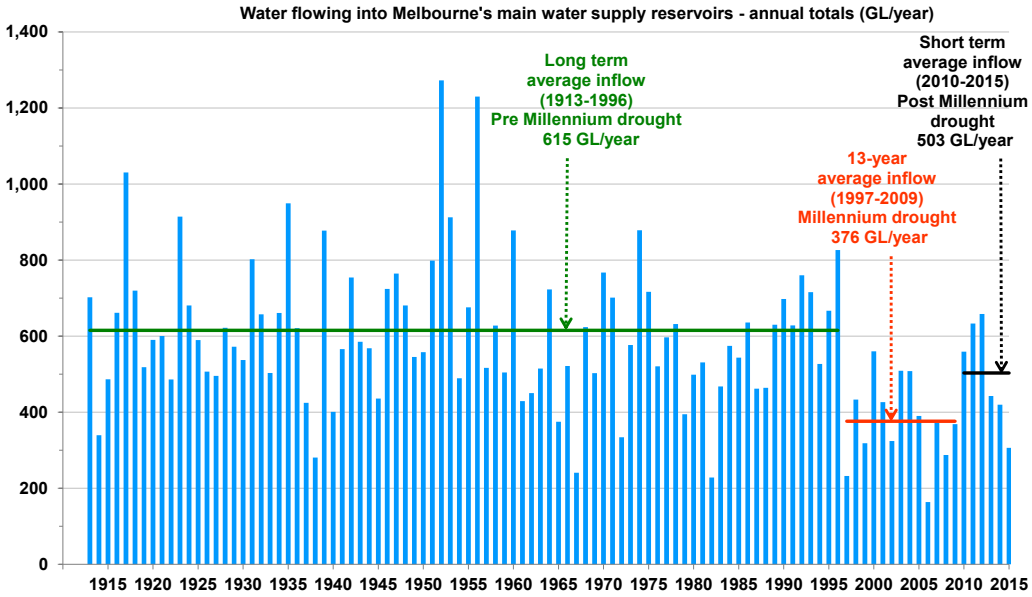
Melbourne and the water supply system

Melbourne is the capital city of the state of Victoria with a population of about 4.5 million (3.5 million in 2001 and 4.2 million by 2011) (ABS 2003, ABS 2012). The city's water comes almost entirely from surface water catchments that feed into a complex series of dams and networked storages, with a large storage capacity, relative to inflow, of about 1,470,000 AF (1,812 Gl) (ATSE 2012). The storage capacity is in the order of four times current annual consumption. Development is restricted in the catchments, which contain large areas of protected forest. Water quality is relatively high. The system is gravity-fed and hence water supply from this rain-fed system is relatively inexpensive.

Melbourne has a temperate climate with warm to hot summers and cool winters, with rainfall on average spread reasonably evenly across the year and dam inflows higher in winter and spring. Inter-annual climate variability is influenced by El Niño and La Niña events, resulting in periodic droughts.

Historically, Melbourne has had a reliable water supply, including through previous dry periods. However, the period from 1997 to 2009 (known as the Millennium Drought) was the longest and driest period that Melbourne had experienced since records began in the 1910s. Inflows were 39% lower than long-term averages during this period (Figure 4.14). Storage volumes began to drop in late 1996, with a period in 2005 when the drought appeared to ease, before inflows fell again the following year and the total system storage of the dams hit a low of 25.6% in June 2009 (Low et al. 2015).

Figure 4.14 – Historical inflows to Melbourne's dam system (source: Melbourne Water 2016). Note: 600 Gl = 500,000 acre-feet.



Melbourne is located near Port Phillip Bay, which receives storm water and treated wastewater from the metropolitan area. The Bay is a low mixing environment and concerns about water quality (especially due to the effect of nutrients) provide another incentive, in addition to concerns about water security, for focusing on storm water and wastewater management, and for a focus on the health of rivers and waterways draining the catchments.

Throughout the Millennium Drought, the Victorian Government, wholesale supplier Melbourne Water, three geographically-separate retailers (City West Water, South East Water and Yarra Valley Water), and regional water authorities connected to the Melbourne system embarked on a number of wide-ranging demand- and supply-side strategies to ensure water security for the city and the environmental health of Yarra River and Port Philip Bay.

Water policy and planning

The coordinated response of the Victorian Government and the water utilities to the Millennium Drought built on existing joint policy and strategy development to plan for and manage Melbourne's water supply system.

In 2004, a Victorian Government policy white paper (Victorian Government, 2004) set targets of a 15% reduction in potable water use and 20% reuse of effluent from Melbourne Water's Western Treatment Plant by 2010. Water authorities were also required to assess the future water supply and demand balance and identify new supply options and demand management strategies based on environmental, social, and economic considerations.

This work informed the 2006 *Central Regional Sustainable Water Strategy* (CRSWS) (Victorian Government, 2006), which addressed supply needs for Melbourne and other cities and towns in the central region of Victoria. This key strategy document, developed in the early stages of the Millennium Drought, emphasized the need for a longer-term vision and approach to ensuring water security, highlighted the importance and value of water conservation as a response to drought, and identified actions for local recycling for non-potable uses and large-scale supply augmentation. The government set a more stringent target of a 25% reduction in total water use from the 1990s average use by 2015, i.e. from 112 to 84 gpcd (423 to 317 lcd) (Victorian Government, 2005). A water supply-demand strategy was developed by the water companies in 2002 and updated in 2006 to support the development of the CRSWS. In Melbourne, water companies have legislated obligations to prepare these strategies and review drought response plans every 5 years.

The policy, strategy and plan development prior to the drought laid the foundation for clarity of institutional roles, and for the identification and deployment of supply and demand strategies during the drought. Despite these efforts, the severity and length of the drought meant that conditions during the Millennium Drought were more extreme than scenarios considered in the supply–demand plan. Thus, while Melbourne's response to the Millennium Drought built on the foundation of prior preparation, it was also characterized by further rapid and adaptive decision-making about both supply and demand measures.

Water demand

Demand in Melbourne has historically been around 60% residential, 30% non-residential and 10% non-revenue water. Average total water demand in the 1990s was 112 gpcd (423 lcd). In the residential sector, less than 20% of demand has been for outdoor purposes (Parliament of Victoria 2009). Water use dropped significantly during the Millennium Drought due to restrictions and other demand management measures, with restrictions implemented from the end of 2002.

Fig 4.15 – Melbourne's total water demand. Note 400 gigalitres = 333,000 acre-feet.

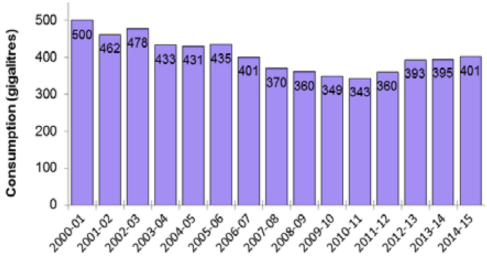
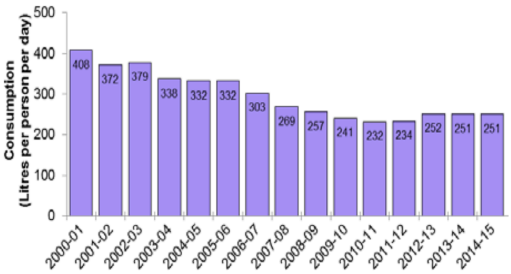


Fig 4.16 – Melbourne's total water demand per person. Note 300 lpd = 80 gpcd.

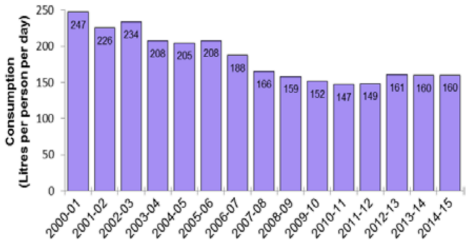


Figures 4.15 to 4.17 (Melbourne Water et al. 2015) show how the total water demand, total water demand per person and residential demand per person changed during and after the drought, which officially ended in 2010 when Melbourne experienced its highest catchment rainfall and inflows since 1996. The lowest demand was in 2010/11 just after the drought and during a period of relatively high rainfall. Since restrictions were finally lifted at the end of 2012, demand has increased slightly but remains much lower than pre-drought levels.

Demand side

Drought response plans are the key framework instrument for managing drought in the state, and Victoria has a long history of structured requirements from drought response planning. Since the 1990s, the Victorian Government has required each urban water authority to prepare a plan which outlines roles and responsibilities, a staged approach to managing demand through restrictions, and in the case of Melbourne, protocols for coordination between utilities.

Fig 4.17 – Melbourne's residential water demand per person. Note 200 lpd = 53 gpcd.



In line with the drought response plan requirements, a Drought Response Coordination Committee was established to coordinate the drought responses of utilities and the Victorian Government (Rhodes 2009). Water restrictions and efficiency programs were implemented by the city's three retail companies and Melbourne Water through a Joint Water Conservation Plan. The retailers managed efficiency programs in the residential, non-residential, and non-revenue water sectors, including the Target 155 (155 lpcd) program that was introduced towards the end of the drought in 2008 (Fitzgerald, 2009). Melbourne's total system storage of the dams reached their lowest levels in 2009. These programs were implemented in combination with a suite of residential rebates available statewide from the Victorian Government's Living Victoria Rebate Program from 2003 to 2015 (DSE, pers. comm. 2015). The "155" target was selected based on modeling of residential consumption expected under stage 4 restrictions (Fitzgerald, 2009).

Restrictions played a central role in drought management in Victoria. Melbourne's drought response plans contained permanent water savings measures (applicable at all times) and four stages of restrictions of increasing stringency, progressively introduced as the drought deepened and predetermined dam level trigger points were reached, consistent with Ministerial Guidelines for preparing DRPs (Victorian Government, 1998). Unlike other states, Victoria applied the same restrictions rules by stage in all cities and towns (although different locations were under different levels of restrictions, depending on local water levels).

Stage 1 restrictions were imposed in Melbourne in 2002 for the first time in 20 years. They progressed to Stage 2 in 2003 and were pulled back to permanent water savings rules in early 2005 when there appeared to be a lull in the drought. Around late 2006, the restrictions were significantly modified and then gradually ramped up to the highest level implemented during the drought, Stage 3a, by 2007, and they remained in effect for 3 years (various sources, see Chong et al. 2009). For residential users the Stage 3a restrictions included: a ban on watering lawns and turf; garden watering limited to two periods of two hours per week (using hand held hoses with trigger nozzles and/or efficient dripper irrigation systems); a ban on car washing at home (with exceptions for windows and mirrors); and a limit on commercial car washing services to a maximum of 18.5 gallons/vehicle (70 L/vehicle).

These stringent restrictions were combined with Target 155 in late 2008 to provide motivation to save more water. The design of the program took on board many of the characteristics of the highly successful Target 140 campaign used in SEQ in 2007. The Target 155 program was a voluntary "call to action" introduced as a concerted campaign to encourage residential water users to reduce their consumption to less than 41 gpcd (155 lcd). With Stage 3a restrictions in place since April 2007, residential water use in 2007-08 had already dropped to 44 gpcd (166 liters/capita/day) (Melbourne Water et al. 2015). The campaign, introduced at the end of 2008, was built on recognizing customers' efforts to date, informing them about the role of Target 155, and assisting them with knowledge about and access to practical solutions. The approach employed:

- mass marketing – a direct mail pack to all households with information and a 4-minute shower timer; advice via print, radio, television, websites, and water conservation kiosks in major shopping centers, plus showerhead exchanges at the conservation kiosks
- personalized marketing – information in quarterly bills to enable customers to compare their usage to the target
- media engagement – media releases about progress against target (Fitzgerald 2009).

Target 155 focused on households but was accompanied by a voluntary Support 155 program for non-residential water users. Support 155 focused on encouraging and providing resources for small and medium-sized businesses (including those using less than 10 million litres of water a year) to assess water use and improve their water use efficiency (Yarra Valley Water 2009).

The communication, promotion and outreach elements of the water conservation campaign were pivotal to its success, and to engendering and maintaining strong community support for water restrictions and other conservation measures in Melbourne. Storage levels and consumption information were highlighted on websites, television news broadcasts, and other media. Information about water conservation and recycling was similarly distributed in bills, on websites, via schools, and through the media. Some of the key programs used in Melbourne during the drought are summarized in Table 4.7.

Table 4.7 – Summary of key demand initiatives

Initiatives	Summary details	Estimated costs, uptake and savings
Residential programs		
Living Victoria Rebate Program (Home and Gardens)	The program ran from 2003 to 2015 and provided rebates on a range of water efficient products in Melbourne and across the state Residential rebates included (with the number of rebates shown in parentheses):brackets)[48]: • indoor – showerheads (9,882), toilets (27,629), dishwashers (4,516), washing machines (19,214), hot water re-circulators (180) • outdoor – pool covers (1,863), high pressure cleaning systems (46,015) • alternative supplies – grey water systems when connected to subsurface irrigation (2,367), tank connection systems (1,968), a range of rainwater tank rebates dependent on size from 1 kl to 10 kl and connection to indoor end uses such as toilet, laundry (30,393) • water conservation audits (11,967) • a 'basket of goods offer' of a USD 22 (AUD30) rebate on products worth over USD 72.40 (AUD100), including flow control valves, mulch, wetting agents, compost/mulch bins, moisture/ rain sensors, garden tap timers, trigger nozzles, drip watering systems/weep hoses, temporary grey water diverters, shower timers, rainwater diverters, waterless car cleaners, and toilet flush interrupters (130,738).	AUD 25M USD 18M 286,732 rebates (Melbourne only)[49]
Retailer showerhead exchange program	The exchange program, which started in 2006/07 and finished in 2010/11, was run by the 3 water retailers. Residential customers exchanged their old showerheads for a free, 3 star water efficient model by bringing in their old showerheads and latest water bill into approved exchange points such as water retailer offices, local government locations, post outlets, hardware stores, and water conservation kiosks in major shopping centers. Some retailers later included free installation of showerheads with energy efficiency equipment.	>460,000 showerheads Measured savings of 8.5 to 12.4 kl/hh/a (Fyfe 2015)

[48] Data provided by Department of Sustainability and Environment, pers. comm. 2015.
[49] Data provided by Department of Sustainability and Environment, pers. comm. 2015.

Retailer toilet replacement program	**The rebate program run by all 3 retailers (including a Living Victoria Water Rebate) included removal and recycling of old units and standard installation of a new 4 or 5 star toilet by a qualified plumber in partnership with a key toilet manufacturer.**	**13,680 toilets (Fyfe 2015)**
Target 155	Target 155 was introduced as a campaign to encourage residential water users to reduce their consumption to less than 41 gpcd (155 lcd). The campaign, introduced at the end of 2008. It was built on recognizing customers' efforts to date, informing them about the role of Target 155, and assisting them with knowledge about and access to practical solutions (Fitzgerald 2009).	
Non-residential programs		
SWEP (Schools Water Efficiency Program)	In 2006, the Victorian Government launched the statewide SWEP. This innovative and highly successful multi-faceted program used a combination of smart meters, a website portal, education and ongoing liaison to help schools to identify leaks, assess their water usage, and promote water efficiency. By 2009, 1,737 schools had joined the program (reported in Low et al. 2015).	
WaterMap (Water Action Management Plan)	During the drought, all business and industrial customers were required to develop and submit to their water utility a "WaterMap" for each site using more than 264,000 gallons/a (10 ML/a). This Victorian Government program built on and extended the voluntary scheme that had been introduced in 2003, in which Melbourne's top 200 non-residential consumers developed water management plans in conjunction with their water utility. The program required and provided support to non-residential water customers to: • assess their current water use • identify inefficiencies and opportunities for water savings • prepare an action plan to implement water conservation activities • report annually on implementation of those activities (Barron and Liubinas, 2009). During the drought, water retailers contacted, approached, and worked with a wide range of businesses across many water-using industries to promote water saving and assist users to save water. Since the Millennium Drought ended in 2011 and with storage recovery following the 2010-11 and 2011-12 La Niña (see BoM)[50], stringent demand management initiatives such as restrictions have no longer been mandatory, but the retailers continue to offer the program on a voluntary basis.	

[50] BoM: Record-breaking La Niña events – An analysis of the La Niña life cycle and the impacts and significance of the 2010–11 and 2011–12 La Niña events in Australia. http://www.bom.gov.au/climate/enso/history/ln-2010-12.

In addition to the restrictions and water efficiency programs, regulations were also in place to encourage water efficiency in buildings. As part of the broader Victorian Star Building Standard (Australian Building Codes Board 2005), a system was introduced in July 2005 requiring new homes to: achieve a 5 star energy rating for the building fabric structure, adhere to maximum flow rates for showerheads and taps, and have a maximum water pressure of 73 psi (500kPa). In addition, new houses must install either (1) a rainwater tank with a capacity of at least 528 gallons (2 kl) for toilet flushing serviced by a 540 square foot (50 sq. meter) roof area, (2) a solar hot water system, or (3) be connected to a reticulated recycled water system where it is available (Australian Building Codes Board 2005). The combination of rebates and regulations on rainwater tanks increased their penetration in Melbourne from 6% in 2004 to 23% in 2010 (ABS 2004, ABS 2010).

It is well documented that Melbourne relied heavily on restrictions in its response to the drought, and that without the combination of various measures such as restrictions, efficiency measures and environmental flow reductions, the city could have come close to running out of water in 2009 as depicted in Figure 4.18.

Fig 4.18 – Historical Melbourne system storage and demand (source: OLV 2013)

This figure demonstrates that the water savings made by Victorians during the recent drought helped prevent Melbourne from running out of water.

Supply side

In 2007, supply and demand options for Melbourne were outlined in the Victorian Government's *Our Water Our Future, The Next Stage of the Government's Water Plan* (Victorian Government, 2007). Two major supply-side projects were:

- the Wonthaggi desalination plant, to supply Melbourne, Geelong, and other towns – 120,000 AF/a (150 GL/a) capacity – the largest desalination plant in Australia
- the 43-mile (70 km) "North-South" Sugarloaf pipeline, to enable water to be transferred from the Goulburn River, in northern Victoria, to the Sugarloaf Reservoir near Melbourne. This was accompanied by the Northern Victoria Irrigation Renewal Project, which aimed to modernize, and reduce losses from, delivery infrastructure and irrigation management, with the savings to be shared between Melbourne, irrigators and the environment.

Both infrastructure schemes were opposed by various stakeholders, including community and irrigation organizations. The Victorian Auditor-General (2008) acknowledged the emergency water security context and the tight timelines required to finalize the 2007 Water Plan, but noted that it was finalized with "minimal stakeholder consultation [and] inadequate levels of rigor applied to estimate the costs, benefits and risks of some of the key component projects."

The Victorian Government's intention in *Our Water Our Future* (Victorian Government 2007) was to "enable Melbourne to move off restrictions to the more secure level of service they historically received." The Victorian Desalination Project was not the most cost-effective option, and was not implemented in a staged way, but nevertheless it was a rainfall-independent source capable of supplying up to 150 billion litres a year, around one-third of Melbourne's annual water consumption. Now constructed, the desalination plant provides insurance against future dry conditions by supplementing Melbourne's existing catchment supplies.[51]

In 2002 the Victorian Government had set a statewide target of reusing 20% of all wastewater inflows to treatment plants by 2010 (Victorian Government 2002). Driven by the joint goals of water security during drought and reducing the nitrogen loading to Port Phillip Bay, this target was exceeded at a statewide level, including in Melbourne where 22.8% of wastewater was recycled in 2009/2010 (Marsden Jacob Associates 2012).

Two Class A recycled water schemes were established in 2005 to supply recycled water from treatment plants to the Werribee and Eastern Irrigation schemes. Melbourne also saw growth in the allocation of recycled water to urban uses, including residential and industrial uses, although the total volumes were substantially less than those used by irrigation schemes.

One example of a residential water recycling scheme that was developed during the drought is the *Aurora Water Reuse Scheme*, developed by Yarra Valley Water. Aurora's water reuse scheme is part of a large-scale greenfield residential development in Melbourne's northern urban fringe. The overall residential development was launched in 2006 and is due for completion around 2025–2030. The scheme was designed to serve 8,500 homes with recycled water for toilet flushing, laundry and garden watering, and public open space irrigation. It took around 8 years to progress from the earliest feasibility discussions to commissioning the recycled water treatment plant in 2009 (ISF 2013). Various operational difficulties constrained the volume of recycled water provided in the early years of its operation, and the costs of the scheme ended up being higher than expected, due mainly to institutional and regulatory changes. Nevertheless, Aurora was valuable because it pioneered a recycling scheme in metropolitan Melbourne and enabled the industry to learn how to identify and deal with operational, institutional, and regulatory risks. Although its overall contribution to recycling volumes is small (about 3% of the overall target), it provided an opportunity for learning within the industry and the utility (ISF 2013).

Table 4.8 – Supply measures implemented during the Melbourne drought (ATSE 2012, PC 2011)

Infrastructure	Capital cost AUD	Capital cost USD	Annual yield GL/a	Annual yield AF/a	Year completed
Desalination (Wonthaggi)	AUD 3,500M	USD 2,500M	Up to, 150,000 Ml/a [potential for approx. one-third of Melbourne's annual water demand]	120,000 AF/a	2012
North-south pipeline	AUD 750M	USD 540M	See below. Up to 75,000 Ml/a	Up to 60,000 AF/a	2010

Aftermath

The Millennium Drought officially ended in 2010 with the highest catchment rainfall and inflows since 1996 (Melbourne Water 2016). By the end of 2011, Melbourne's dam levels had recovered to around 65% and remained between 65% and 80%.[52] With a total dam storage

[51] DELWP (2016) Victorian Desalination Project. http://www.depi.vic.gov.au/water/urban-water/desalination-project
[52] http://www.melbournewater.com.au/waterdata/waterstorages/Pages/Storages-over-the-years.aspx

capacity that is large compared to mean annual inflow, the inter-annual carryover of Thomson is a key factor underpinning drought security.

Due to the availability of surface water since the drought was broken, the 120,000 AF/a (150 Gl/a) Melbourne desalination plant (the largest in Australia) has not been used because Melbourne's dams did not fall to levels that require supply to be ordered from the plant. This is similar to events which have occurred in other jurisdictions.

Also, due to the availability of low-cost surface water from Melbourne's dams, the North-South pipeline has seen limited use. The North-South pipeline was completed in early 2010 and operated for only 6 months that year, following a change of government in Victoria in late 2010. A pre-election commitment by the new government resulted in the North-South pipeline being used in times of 'critical human need'. This means the pipeline will only be used when the combined volume of Melbourne's dams goes below 30% of full capacity on 30 November in any year, or when there is a need to use the pipeline's off takes for fire-fighting purposes (Melbourne Water 2012). This has resulted in very limited use since 2010.

In addition, water restrictions were lifted in late 2012 (while permanent water savings rules remain applicable at all times), and the long-established state government water efficiency rebates finally closed in 2015. As a result of the rebates closing, most of the water retailer programs have also closed. Since the drought, water utilities in Melbourne continue to work on more holistic integrated water management approaches to delivering Melbourne's urban water services. This includes making use of alternative water sources – like recycled water and stormwater – to reduce pressure on our drinking water supplies while improving the livability of our communities.[53]

Key lessons

Managing crisis and opportunity

Water management strategies implemented as drought response strategies (as well as long-term strategies) highlighted how water shortages can drive both innovations, with long-term benefits, and crisis-driven, politicized decision-making. The utilities and the state government embarked on a range of water conservation initiatives and the drought represented an opportunity to target a wide range of users, and to commence exploration, research and testing of innovative new approaches to restrictions (although these were not ultimately implemented). Water efficiency programs that achieved structural changes had a longer-term impact on water savings, ongoing water security during drought, and deferral of need for augmentations. Also, as the drought worsened, large-scale supply-side infrastructure investments that had previously not been considered as part of planning processes were rapidly put forward. Several of these large-scale, supply-side schemes were implemented and may be viewed by some as politically unpopular and financially costly compared to other more cost-effective options to save or supply water and didn't incorporate staging that could have saved billions of dollars of unnecessary investment. However, now constructed, the Victorian Desalination Project (VDP) is a rainfall-independent source of water that could supplement Melbourne's existing catchment supplies in the future.

Working together

Melbourne's Drought Response Coordination Committee – which included representatives of the state government policy and program agencies, the bulk or wholesale supplier, and three retailers – demonstrated the importance and value of institutional coordination to enable implementation of a cohesive, effective water savings program during drought. The water utilities and government also collaborated significantly on investing in critical research, and in monitoring, evaluating, and modeling to support effective water efficiency programming. This collaboration ranged from end use assessment and modeling, to investigating new and innovative approaches to responding to drought.

Melbourne's three metropolitan retailers have drawn on lessons from the drought to revise the Drought Response Plans to incorporate a more adaptive water management approach for Melbourne's water security and drought response (Tan et al. 2015). A key element is

[53] http://www.melbournewater.com.au/whatwedo/Liveability-and-environment/Integrated_Water_Management/Pages/Integrated-water-management.aspx

collaboration between Melbourne Water and the three retailers to produce an annual "Water Outlook for Melbourne" (Melbourne Water et al. 2016) that includes information on water storages, use, system performance, and water security action plans (including both supply and demand options) corresponding to three "zones" of water security, "high", "medium" and "low".

Speaking and listening

In Melbourne, regular customer surveys indicated strong support for restrictions throughout most of the drought, and the water conservation, efficiency, and restriction programs introduced by the Victorian Government, Melbourne Water and the three retailers sought to include and communicate to a wide range of users across sectors. This promoted the "all in it together" sentiment crucial for public support and action on water conservation. However, at higher levels of restrictions, which resulted in ongoing impacts on public and private gardens, support for restrictions waned.

The planning processes leading up to the drought, including for the CRSWS, included strong community engagement. There was significant community engagement during the drought period to understand preferences and needs, for example around restrictions. However, during the drought, community engagement to inform major supply decisions was not as strong.

Picking the low hanging fruit

As in other jurisdictions, analysis was undertaken on the potential for accelerated water efficiency options to "flatten the depletion curve" of water storages, in order to defer the capital investment for large-scale supply options to come on line. In Melbourne, integration of short-term and long-term impacts – through the inclusion of drought response measures within a long-term water supply and demand strategy that incorporates the impact of population growth and climate change – was key to water system planning undertaken prior to the drought. However, the large-scale supply investments implemented were contentious in terms of impacts, costs (relative to other options) and concerns about taking water from water-stressed rural areas, while others considered these augmentations as insurance policies against drought and climate change.

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