Water Resource Management and Drought: What can Southern California Learn from Australia's Millennium Drought?

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Executive Summary

Australia experienced a devastating 12-year 'Millennium Drought' that lasted from 1997-2009. Four years in, their drought was just like California's - big and devastating. The country responded by overhauling their existing water governance framework and implementing a host of water management solutions, ranging from desalination facilities to comprehensive water conservation behavior change programs. Some of these solutions worked and helped Australia make efficient use of their dwindling water supplies. Other solutions, however, proved challenging, with exorbitant costs and lengthy construction times cancelling the benefits associated with additional water supply. Southern California has a lot to learn from these lessons as the state's decision makers weigh options of how to deal with our current water crisis.

This research project examines the drought-response strategies from the two Australian cities of Melbourne and Adelaide, and how these strategies might be applied to southern California. Both of these cities implemented innovative water management solutions during the Millennium Drought that helped to both drought-proof their respective water supplies, and also to increase water-supply resiliency in the future with a changing climate. Southern California has the rare opportunity to not only learn from what water management solutions worked in Australia, but also from what water management solutions did not work. An analysis of these critical successes and challenges is integral to understanding how southern California can not only best address its ongoing drought, but also to lead the state forward on a better, more water and climate resilient path. Through these learning's, southern California can position itself to lead the nation in transforming how water is managed: from optimizing efficiency, to changing residents' behavior around water, to developing alternative water sources, to enhancing and restoring natural processes. The following lists both the lessons learned from Adelaide and Melbourne in their response to the Millennium Drought, and also policy recommendations that southern California can use to address its current drought based on Melbourne and Adelaide's experience.

Lessons Learned:

1. *Historical records are not accurate predictors of the future, and urgent actions need to be taken during drought conditions.*

If Melbourne had not acted during the 12-year drought to aggressively pursue water conservation, their storage reservoirs would have run dry by July 1, 2009. This cautionary tale stresses the importance of: a) implementing drought-response strategies early on during a given drought; and b) not relying on historical records to predict the severity of future water scarcity events. Further, the Millennium Drought also shows that public and elected officials are receptive to large changes in water policy during times of water scarcity, and both Melbourne and Adelaide were able to utilize the drought as a window of opportunity to implement both supply- and demand-side measures that they would have proven difficult during normal precipitation years.

2. *Begin Transitioning Towards a Whole-of-Water-Cycle Approach to Water Management.*

Both Adelaide and Melbourne restructured water management frameworks multiple times to better facilitate urban water management and increase collaboration among urban planning, public health, industry and natural resource management. By doing so, the efforts helped to facilitate community-level engagement in identifying and prioritizing both supply and demand side water management options. This ensures that all stakeholders and appropriate water management authorities work together to develop projects - rather than in isolation - in order to maximize shared benefits

3. *Alternative Water Sources can Increase Water System Resiliency.*

Adelaide and Melbourne employed a mix of alternative strategies related to wastewater recycling, managed aquifer recharge, rainwater harvesting, and stormwater capture during the drought. These projects are primarily used for irrigating public green spaces with non-potable, fit-for-purpose water (or water that is treated only to its intended end use), and help to maximize strained potable water supplies during times of water scarcity.

4. *Balancing Water Scarcity Planning with Other Needs.*

Drought-stricken public green spaces and vegetation were unable to provide shade and ecosystem services during a severe Melbourne heat wave in January of 2009. As a result, the urban heat island was greatly intensified and 980 people died (Norton et al., 2015). This caused Melbourne to rethink the way drought restrictions impact public green space and the city is now focused on doubling its urban forest canopy cover to cool the system by 7.2 degrees Fahrenheit. All new green spaces are irrigated with non-potable, fit-for-purpose water from recycled water and stormwater harvesting projects.

5. *Public Behavior Programs around Water Conservation can be Extremely Effective.*

The Millennium Drought resulted in residents of Adelaide and Melbourne dramatically changing their behavior around water consumption. This was accomplished most effectively through a mixture of efforts related to public education, target setting, social comparisons, water restrictions, efficiency labeling, rebates, and water pricing. Daily per capita water use was reduced substantially for residents of both Adelaide and Melbourne, and by the end of the drought Adelaide averaged 60 gallons per person per day, and Melbourne averaged 65 gallons per person per day (Grant et al., 2013; Maier et al., 2013).

<u>Southern California Policy Recommendations:</u>

Table ES-1: Overview of Southern California Policy Recommendations

Policy	*Focal Area*
Increase Agency Collaboration and Transition to Whole-of-Water-Cycle Management to Facilitate Multi-Benefit Projects	Whole-of-Water-Cycle Planning, Alternative Water Sources, and Drought Urgency
Create a Cost-Benefit / Co-Investment Tool to Quantify Water Supply, Water Quantity and Other Benefits to Increase Collaboration Across Fields	Whole-of-Water-Cycle Planning, Alternative Water Sources, and Drought Urgency
Set Aggressive Targets for Stormwater Capture and Reuse, Rainwater Harvesting, and Wastewater Recycling.	Alternative Water Sources and Drought Urgency
Ban the Use of Potable Water to Irrigate Outdoor Landscaping and Focus on Incentivizing Alternative Water Sources in New Development	Alternative Water Sources and Drought Urgency
Provide Incentives and Rebates for Water Efficient Appliances and Fixtures, Including Rainwater Harvesting Systems and Graywater Systems	Alternative Water Sources and Drought Urgency
Set Aggressive Regional Cooling and Tree Canopy Targets	Balanced Planning
Create Guidance to Protect Liveability and Health When in Drought Situations	Balanced Planning
Increase Locally-Sourced Water Supplies to Ensure that Environmental Flows are Met in California	Balanced Planning
Create an Integrated, Clear and Consistent Messaging Campaign	Public Behavior Change and Whole-of-Water-Cycle Planning
Increase the Cost of the Non-Essential Use of Water	Public Behavior Change
Deliver Social Comparisons of Water Consumption	Public Behavior Change
Set Aggressive Water Consumption Targets	Public Behavior Change

This report will describe these lessons and policy recommendations in greater detail, and will highlight how southern California can begin transitioning towards sustainability and water resiliency in a future with a changing climate. Melbourne and Adelaide leveraged their drought to make critical changes to their water systems that has made them world-leaders with respect to innovation and progression in the water sector. Southern California now has the same opportunity, and the state needs to act quickly to both safeguard its water supply and ensure that policies will be in place for future droughts in order to avoid the severe vulnerabilities that the current drought has exposed in the state's outdated water management system.

Introduction

Overview

In searching for solutions to ensure urban water supply resiliency in the face of drought and climate change, Australia offers an ideal case study on drought-response strategies for southern California. Some Australian strategies -- like water restrictions, alternative stormwater and rainwater capture systems, tiered water pricing and collaborative governance -- worked well and helped Australian states maximize their limited water resources during the drought. Other strategies -- like desalination facilities and interbasin transfer pipelines -- did not work as well, as their lengthy construction period rendered increased water supply benefits only *after* the drought had ended, leaving taxpayers to foot the bill. This report emphasizes these lessons with the hope that they be modified and applied rapidly as viable drought-response strategies in southern California.

California's Drought and Changing Climate

California is currently in the fourth year of one of the worst droughts of the past century. 2013 was the driest year on record, and may have been the driest in the past 500 years (UC Berkeley, 2014). Drought conditions are exposing severe water resource management vulnerabilities for water providers throughout the state, with current reservoir storage capacity at 52% in comparison with average storage conditions (DWR, 2014). As of December 16, 2014, California needed approximately 11 trillion gallons to recover from the ongoing drought (NASA, 2014). Further, climate models indicate that southern California will become increasingly arid, with longer and more severe droughts. Southern California has historically met water demand largely through partially federally- subsidized imported water sources derived from Northern California, the Owens River Valley, and the Colorado River. However, several factors are currently placing stresses on the region's water supply system, including population growth, decreasing snowpack, climate change, and environmental regulations limiting water exports. These stresses have forced southern California to explore new water supply sources and water demand interventions that may be utilized to diversify its water supply portfolio and provide water for a growing population under drought conditions.

Australia's Millennium Drought

Australia went through a devastating 'Millennium Drought' that lasted from 1997 to 2010. This drought resulted in the country's longest period of rainfall deficit on record, and profoundly affected the country's environment, economy, and national psyche. It produced changes to the way Australia manages its water, and created a political atmosphere supportive of deep investment and rapid innovation that accelerated reforms to water laws and institutions that were already under way (Gleick et al., 2012). While previous droughts were limited to specific regions of the country, the Millennium Drought differed in that it covered most of the continent in the course of several years. Each of Australia's most- populated cities – Sydney, Perth, Melbourne, Brisbane, and Adelaide – was impacted, along with the nation's food producing regions, particularly the Murray-Darling Basin in southeastern Australia (Gleick et al., 2012).

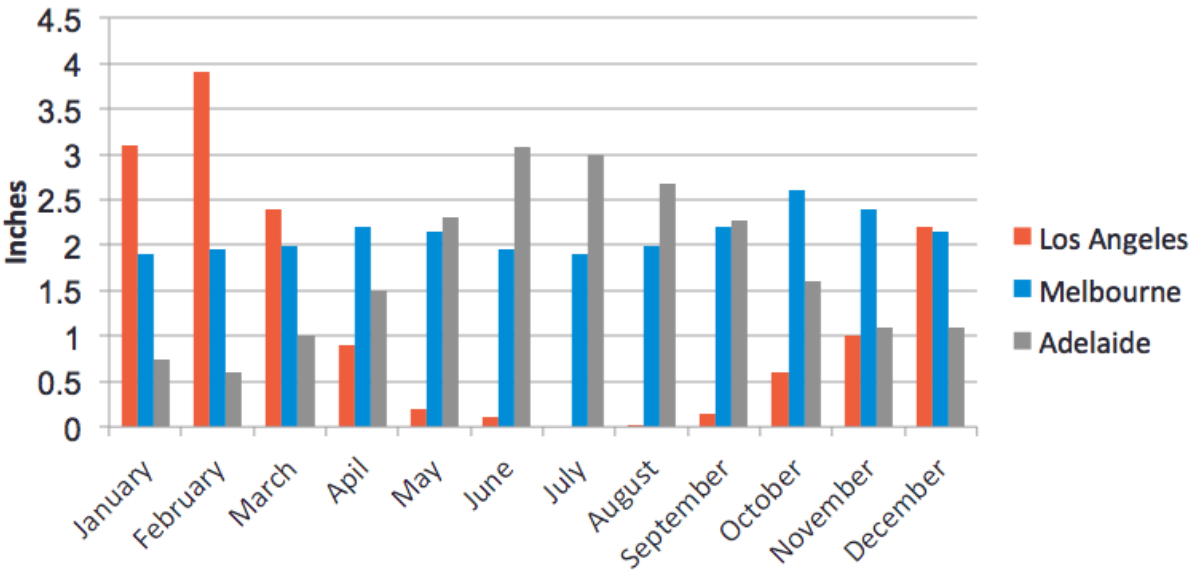
Why Australia?

Australia is the world's driest inhabited continent, and also heavily urbanized, with approximately 89% of the country's 21 million inhabitants living in urban areas. Ensuring that residents of Australian cities have access to water resources is an ongoing challenge that the country has dedicated immense resources to. Australia shares several similarities with southern California that makes the country an ideal case study for analyzing drought response strategies. Both Australia and southern California: 1) enjoy a high standard of living and contain similar lifestyles; 2) are subject to wet and dry seasons and consistent drought; 3) are projecting increases in population for major metropolitan areas; and 4) have similar water management and governance systems. However, notable differences arise when comparing the two regions geographic scales: Australia has a total population of 23 million and is 2.97 million square miles; whereas southern California has a population of 23 millions and is 56,500 square miles (southern California is ~2% of Australia's total landmass).

The two Australian cities of Melbourne and Adelaide offer particularly relevant examples of drought-response strategies for southern California. The Millennium Drought greatly impacted these cities, and both were forced to reshape their water management strategies accordingly. Melbourne is located in the state of Victoria, in southeastern Australia, and has a moderate oceanic climate with average annual rainfall totaling approximately 25 inches (see Figures 1 and 2). Adelaide is located in the state of South Australia and contains a similar Mediterranean climate to that of Los Angeles, with hot, dry summers and cool, wet winters (see Figure 1). Historic average annual rainfall is approximately 17 inches in Adelaide, and 15 inches in Los Angeles (see Figure 2). Of all of Australia's capital cities, Adelaide has a climate pattern and average annual precipitation that most closely approximates that of Los Angeles.

Figure 1: Melbourne and Adelaide, Australia (Victorian Government, 2008).

Figure 2: Average Annual Rainfall for Adelaide, Melbourne, and Los Angeles (City of Melbourne, 2014a; Australian Bureau of Meteorology, 2015).



Objectives

This paper will provide: a) a background of the Australian federal policy response, as well as the state level policy responses in Victoria and South Australia, to the Millennium Drought; b) an overview of the key themes that emerged over the course of the research project; and c) an overview of the barriers associated with transferring Australian drought management strategies to California; and d) recommended policies that southern California could utilize to respond to its current drought.

Research Methodology

Overview

Research for this project was accomplished over a seven-month period in Los Angeles, California; Melbourne, Australia; and Adelaide Australia. Information was gathered from stakeholders, water managers, environmental groups, urban planners, and government agency personnel, both in Australia and California. This was accomplished with the following three research methods: a) document analysis; b) a TreePeople and Energy Coalition sponsored Australian Study Tour; and c) semi-structured interviews. Each of these research methods is described in greater detail below.

Document Analysis

An initial literature review was conducted from June 1st, 2014 – September 1st, 2014. This review identified relevant research in translating Australian drought management strategies to southern California, and also identified relevant organizations and individuals in Los Angeles, Adelaide, and Melbourne to reach out to in order to set up in-person interviews.

The Energy Coalition and TreePeople Sponsored Australia Study Tour

I attended the Energy Coalition and TreePeople sponsored Australian Study Tour from October 21st – October 27th in Melbourne and Adelaide Australia. The tour was comprised of 17 California water leaders from government, private organizations, and environmental organizations, and met with water leaders from Australia who shared projects and presentations relevant to California. The goal of the Australian Study Tour was to understand that Australia offers immediately implementable solutions for California's drought that also addresses significant water supply, climate, and infrastructure needs. Objectives of the tour were to: a) identify the costs and benefits, as well as successes and lessons learned, from Australia's multi-agency governance structures and policies; b) identify what governance, technical and programmatic solutions are transferable to Los Angeles and other cities; c) understand Australia's drought-response timing and opportunities to accelerate programs and policies for Los Angeles and California; and d) build a greater esprit de corps resulting in a viable team-based collaboration upon returning to California to help implement appropriate Australia-inspired solutions in Los Angeles and California.

Semi-Structured Interviews

I conducted semi-structured, in-person interviews with stakeholders, academics, water managers, environmental groups, urban planners, and government agency personnel in Los Angeles, CA; Melbourne, Australia; and Adelaide, Australia. Interviews were typically between 30 – 60 minutes and involved a prescribed set of questions related to the subjects' expertise. In Los Angeles, interview questions were structured to answer the following questions: 1) what urban water management strategies are currently being explored by Los Angeles?; 2) what is the projected cost of implementing these urban water management strategies?; and 3) what are the environmental constraints associated with each of these urban water management strategies?. In Melbourne and Adelaide, interview questions were structured to answer the following questions: 1) why were specific urban water management strategies implemented?; 2) how much did each of these urban water management strategies cost?; 3) what was the public perception of each urban water management strategy during and after the Millennium Drought?; and 4) how does each urban water management strategy function during wet years?

A list of all people and affiliated organizations that were interviewed for the project can be found in Appendix A.

Australia: Background

Differences Between Australian and United States Governance Structures

Institutional differences between the Australian and American political systems stem from distinctions between the U.S. federal republican system and Australia's parliamentary system. In the U.S., a popular vote elects the President and congressional representatives, where the President is the head of state and appoints the administrators of federal agencies, subject to the approval of Congress. In Australia, ministers - or any politicians who hold significant public office - are elected to Parliament by popular vote, and the majority party elects a Prime Minister from its ranks. The Prime Minister directly appoints ministers from the party to head federal agencies.

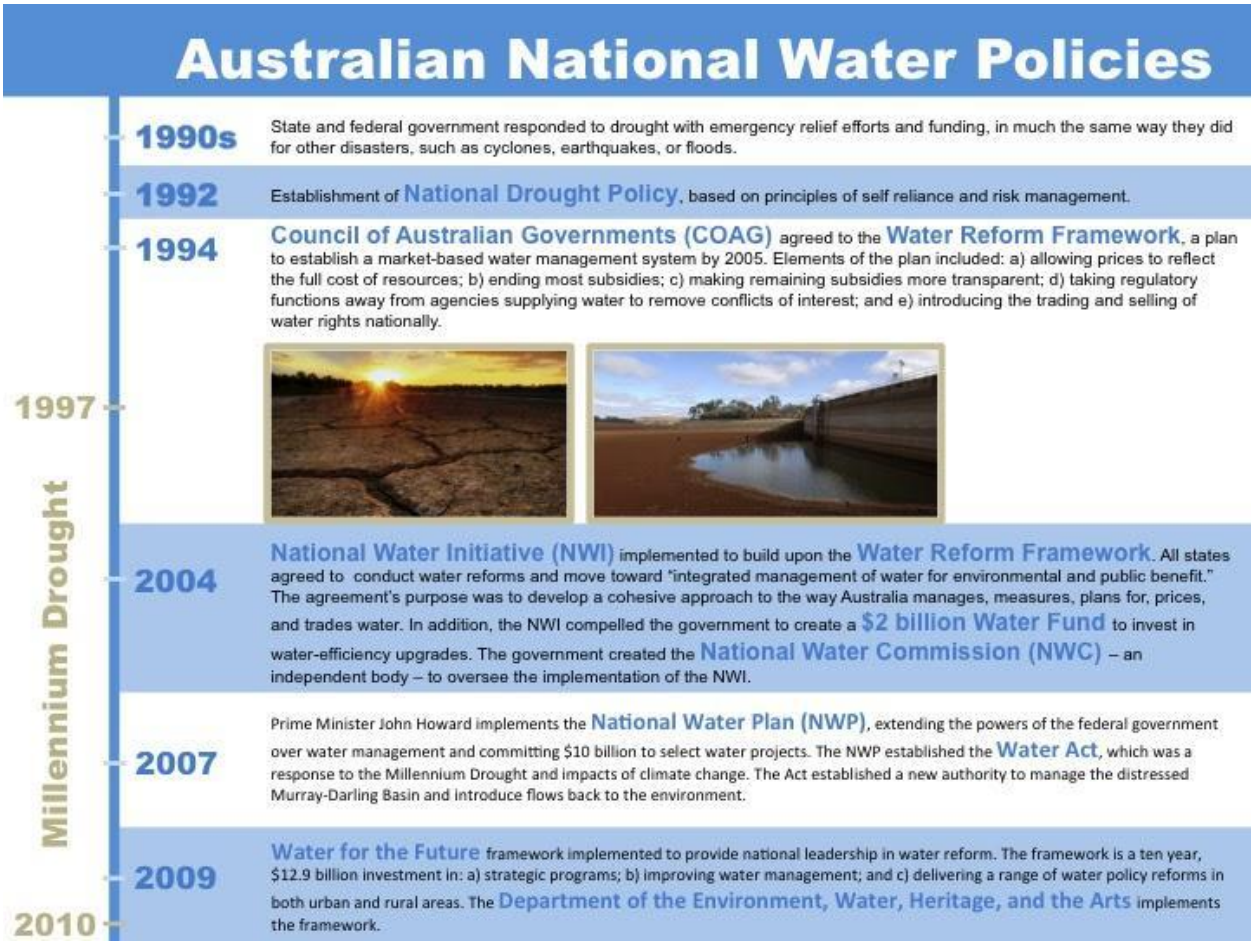
State level governance generally mirrors federal governance in both countries; however, states have considerably more power in Australia than in the United States. Australian states have primary responsibility for environment and natural resource management, whereas in the U.S. this responsibility is held under the federal government and often delegated to the states by federal agencies. As a result of this, U.S. federal agencies are more commonly involved at the state and regional level in both direct and oversight roles (Margerum, 1996).

Local government structure in Australia and the U.S. also differs. In Australia, more powers -- such as education, police and fire protection -- are controlled at the state level. Local governments often oversee services related to building regulations and development, public health, local roads and footpaths, parks and playing fields, libraries, local environmental issues, waste disposal, drainage, and many other community needs. Further, many Australian states have reduced the number of local governments as well as the number of local water/wastewater agencies through amalgamation, an action that is rare in America (Margerum, 1996).

Australian Federal Government Response to Drought

In Australia, the right to manage water is governed by the states. However, during the Millennium Drought federal involvement was increased to expedite reforms set forth by the Council of Australian Governments (COAG) – an organization consisting of the federal government, the six states and two territories, and the Australian Local Government Association - in the 1994 Water Reform Framework. The result was the 2004 National Water Initiative (NWI), a blueprint for water reform that highlights water efficiency as a top priority. Following the NWI, the National Water Plan was implemented to establish the Water Act and provide $10 billion in funding for selected water projects. The Water Act created the Murray-Darling Basin Authority and established the Bureau of Meteorology as the major custodian of all water-related data including collection, publication, and implementation of water information standards. The federal government also provided $12.9 billion in funding in 2008 for the Water for the Future Plan, a plan dedicating funds largely to infrastructure improvements, irrigation efficiency projects, and buying back water from irrigators to reintroduce back into the environment (AWE, 2014) (see Figure 3).

Figure 3: Australian National Water Policies.



Water markets have also been part of the federal government's efforts. Water markets allow the buying and selling of water from various water systems and political boundaries in order to ensure water is allocated to its highest value use during a shortage. The market apportions water for the environment by putting a cap on the amount of water available for consumptive use (AWE, 2014).

Melbourne Water Management Overview

In Melbourne, Melbourne Water is the Victorian government-owned wholesaler of water supply, sewage treatment and recycled water services. Melbourne Water sources its potable water primarily from protected catchments that deliver water by gravity into ten harvesting reservoirs. From these reservoirs, water is then distributed through a network of aqueducts and pipelines to local service reservoirs. Melbourne Water also sources water for non-potable uses through stormwater harvesting, rainwater harvesting and recycled water from the Eastern and Western Treatment Plants. Three Victorian government-owned water corporations - Yarra Valley Water, City West Water, and South East Water – purchase and sell drinking water from Melbourne Water and provide sewage services for their respective jurisdictions. Since the mid-1800s, Melbourne's protected catchments have provided the city with safe, low-energy and reliable high-quality drinking water. However, the single potable water supply source has left the city vulnerable to water shortages during periods of drought.

During the Millennium Drought, Melbourne's four major harvesting reservoirs dropped by as much as 64% in comparison with their long-term average (a decline of around 73,000 acre-feet per year) (see Figure XX). To address this, the Victorian government offered water-efficiency rebates, provided education and technical assistance, developed statewide uniform guidelines for local water corporations to enhance water saving rules and water restrictions, and facilitated water trading. The City of Melbourne imposed severe water restrictions, and from January 2007 to August 2010 Stage 3 (out of 4) efforts were in place, completely disallowing activities such as using potable water for lawn watering (AWE, 2014). These efforts resulted in per capita municipal water demand dropping by 46% over a 12-year period in Melbourne, from 121 gallons to 65 gallons per person per day (Grant et al., 2013). As a comparison, current per capita water use in the City of Los Angeles is about 131 gallons per person per day.

The Victorian government also built:

- a seawater desalination plant (Wonthaggi Desalination Plant) capable of supplying 121,600 acre-feet (AF) / year (Y) of water at a cost of $6 billion (AUD) (Grant et al., 2013); and
- an interbasin transfer pipeline (the North-South Pipeline) capable of supplying 60,800 AF / Y of water at a cost of $700 million (AUD) (Grant et al., 2013).

Combined, the two new sources can deliver approximately 40 percent of the city's present-day municipal water demand (Grant et al., 2013). However, upon both projects' respective completion date, neither has supplied the city with water. This is due to: a) both projects being commissioned during the Millennium Drought and completed after the drought was over; b) public concern over the carbon footprint and the very high economic cost of producing water

from the desalination plant; and c) the politically unpopular idea of transferring water from already water-stressed rural regions via the North-South Pipeline (Grant et al., 2013).

Following the drought, water restrictions in Melbourne were lifted and permanent water use rules were kept in place. These rules included requirements regarding handheld hose use, garden and lawn watering, fountains and water features, and cleaning of hard surfaces. Also, Drought Response Plans for Melbourne's three water retailers - Yarra Valley Water, City West Water and South East Water - were revised in 2011 to incorporate the Water Outlook Approach, an adaptive management strategy based on experiences of the Millennium Drought. The plan requires the three water retailers and Melbourne Water to jointly publish a *Water Outlook* for Melbourne by the first of December annually. The *Water Outlook* is a summary of Melbourne's water supply and demand, and includes short- and medium-term strategies to manage water security. These strategies include: efficiency programs, planning, education, benchmarking, water loss control, rainwater harvesting, recycled water, stormwater harvesting, and water restrictions (AWE, 2014).

The Victorian government also appointed the Ministerial Advisory Council (MAC) to provide independent advice on urban water management. In 2011, the MAC responded with the *Living Melbourne, Living Victoria Implementation Plan*, a plan recommending key priorities to improve Melbourne's water management to bring about benefits including healthier urban waterways, greener open spaces, reduced urban heat-island effect, future water security, and decreased reliance on rural water. The plan called for three strategies:

> 1) overhauling the existing water planning framework to better respond to broader community and environmental needs and more effectively integrate with urban planning;
> 2) transforming the way water resources and the water system are managed; and
> 3) establishing the Office of Living Victoria (OLV) to drive reforms by coordinating urban and water planning.

Adelaide Water Management Overview

In Adelaide, SA Water is the South Australian government-owned water corporation that provides water and wastewater services to the city. SA Water draws its water from numerous sources, including: 1) the River Murray; 2) stormwater for non-potable use; 3) Managed Aquifer Recharge projects for non-potable use; 4) recycled water for non-potable use; 5) protected catchments in the Adelaide Hills; and 6) the Adelaide Desalination Plant. Most of the city's water supply is from the nearby catchments in the Adelaide Hills; however, during dry years 90% of water needs are met with water that is pumped from the River Murray.

During the Millennium Drought, the severe impacts on the Murray-Darling Basin rendered the city unable to use much of the Murray River water to meet its supply needs. As a result, compulsory water restrictions were introduced in 2003, and in 2005 the South Australian government developed the *Water Proofing Adelaide* plan. The goal of the plan was to develop a longer-term planning approach to secure Adelaide's water resources until 2025. The plan

established that by 2025, Adelaide's water supply would have an annual shortfall of 32,430 AF during drought years, and new supply and demand interventions needed to be implemented. On the supply side, the plan determined that rainwater harvesting tanks and loss reduction strategies were economically feasible and suitable for implementation. On the demand side, a goal to reduce annual demand by 28,375 AF by 2025 was established. The strategies aimed at achieving these supply and demand interventions were to: a) implement permanent water conservation measures; b) introduce a nationally recognized water efficiency labeling scheme (WELS); c) educate the public through various programs; d) require all new dwellings to have rainwater tanks plumbed into the house; and e) implement leak detection programs to minimize water losses in the reticulated system. However, initial demand strategies were largely ineffective, as the only compulsory restriction was the prohibition of outdoor watering in the middle of the day; the rest relied on voluntary responses from customers (Maier et al., 2013).

As the drought continued to worsen and flows in the Murray River dropped to historically low levels, the government responded by introducing temporary water restrictions and permanent water conservation measures that were outlined as part of the *Water Proofing Adelaide* strategy. These actions had a tremendous impact on people's behavior and had a visible public impact, as many public fountains were turned off and public parks turned brown. Further, as an effort to implement some of the voluntary strategies outlined in *Water Proofing Adelaide*, the government offered rebates on water-saving devices, such as water-saving showerheads and front-loading washing machines (Maier et al., 2013).

Water restrictions had a tremendous impact on people's lives, prompting numerous community discussions on how the government should address Adelaide's water supply shortfalls. Desalination and stormwater capture and reuse (including rainwater harvesting) were determined to be suitable alternative water supply sources, and the government responded by commissioning a 81,070 AF / Y desalination plant for potable needs and a study looking into urban stormwater harvesting for nonpotable uses (though in reality, many residents used rainwater harvesting tanks during the drought as a potable water source). The government also produced a new water security plan, *Water for Good*, that was implemented in 2009 to replace *Water Proofing Adelaide* with a planning horizon to 2050. The more aggressive plan recognized the inadequacies of Adelaide's current water supply and advocated a mixture of new supply types, most notably the 81,070 AF / Y desalination plant and supplemental stormwater and recycled water projects. These projects were funded with increases to the water pricing structure, with annual water prices doubling for Adelaide residents. The plan also included demand management incentives, such as rebates for water-saving appliances, and outdoor water conservation measures, such as rebates for garden mulch. These demand management and water restrictions resulted in a reduction of Adelaide's per capita water consumption from 87 gallons per person per day in 2003 to 60 gallons per person per day in 2009 (Maier et al., 2013). Further, incentives for rainwater harvesting tanks resulted in ~50% of Adelaide residents owning rainwater harvesting systems by the end of the drought.

Following the drought, *Water for Good* continued to guide Adelaide's water management. The plan is a 'living document' that is reviewed on an annual basis; therefore changes can be made

each year to strengthen the plan's stated objectives of: 1) reforming urban water legislation to support the efficient and effective delivery of water and wastewater services; 2) pursuing water pricing that reflects the true value of water; and 3) developing a holistic urban water strategy linking all existing strategies together to achieve the high level objectives in *Water for Good* (DEWNR, 2010). A stormwater strategy was developed that aimed to move away from *ad hoc* projects and transition towards an integrated stormwater planning framework linking urban planning, public health, and natural resource management. To that end, the Department of Water was formed in 2010 to take control of water management and provide a focal point for the integration of water management activities. In 2012, the department was amalgamated into the Department of Environment, Water and Natural Resources to better facilitate the integration efforts (Bettini, 2012).

Key Themes that Emerged During Research

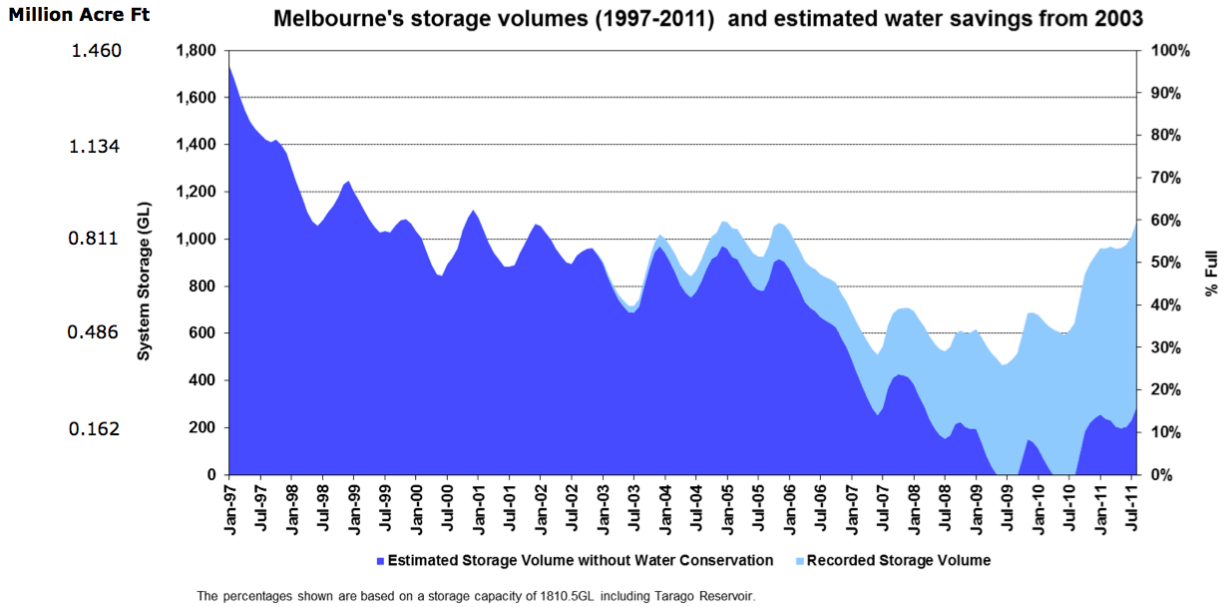
The following key themes emerged over the course of the research project:

1. Historical records are not accurate predictors of the future, and urgent actions need to be taken during drought conditions.

Australia's experience shows that it is impossible to rely on historical records to predict when a drought will end. Prior to the Millennium Drought, the City of Melbourne was historically able to meet water demand since the mid-1800s with its four reservoirs and source water protection program. However, given climate change and human disturbance in river basins, stationarity - the idea that natural systems fluctuate within an unchanging window of variability - is no longer an accurate metric that can be utilized when planning for water supply (Milly, 2008).

The Australian government agencies realized that they could no longer count on history to predict the future. For example, if Melbourne had not acted during the 12-year drought to aggressively pursue water conservation, their storage reservoirs would have run dry by July 1, 2009 (see Figure 4). This cautionary tale stresses the importance of: a) implementing drought-response strategies early on during a given drought; and b) not relying on historical records to predict the severity of future water scarcity events. Deferring hard decisions – like implementing robust behavior change programs and decentralized water infrastructure strategies – leads to more difficult decisions and costly options over time. Because behavior change strategies and decentralized water infrastructure have long incubation times, and require a sustained level of commitment, it is important to act rapidly to implement these programs early on during periods of water scarcity.

Figure 4: Melbourne's Water Supply with and without Water Conservation Measures (City of Melbourne, 2014b).



The Millennium Drought also shows that the public and elected officials are receptive to large changes in water policy during times of water scarcity. Searing images of Melbourne's dried up storage reservoirs galvanized the public to embrace water conservation measures, and also allowed the Victorian Government to: a) improve water use efficiency through rebates on water saving fixtures and appliances; b) implement tiered pricing structures to accurately value water; c) effectively restrict water use in accordance with water restriction plans; d) set aggressive per-capita water consumption targets; e) pursue the reuse of wastewater and capture of stormwater at scale; and f) build a desalination facility and interbasin transfer pipeline. While Melbourne's desalination facility and interbasin transfer pipeline were largely mothballed due to high-energy costs and the drought ending before they became operational, they provided a critical 'water supply safety net' that empowered the government to adopt the progressive *Living Melbourne, Living Victoria* initiative in 2011. This initiative is transforming the way urban water is managed in Victoria, and provides critical funding for whole-of-water-cycle projects and decentralized infrastructure.

2. Whole-of-Water-Cycle Planning is Effective and Facilitates Projects with Multiple Benefits

Collaborative Approach to Water Governance

During and after the Millennium Drought, both Adelaide and Melbourne restructured water management frameworks multiple times to better facilitate urban water management and increase collaboration among urban planning, public health, industry and natural resource management. By doing so, the efforts helped to facilitate community-level engagement in identifying and prioritizing both supply and demand side water management options. These options included reducing household water use, incorporating plans for using low-quality treated

rainwater for nonpotable needs, capturing stormwater runoff through biofiltration and recycling wastewater. This process encouraged bottom-up collaboration among stakeholders, enhanced social learning among the public regarding the severity of the drought and helped generate a broad public consensus, which, in turn, empowered city officials to embrace a wide and diverse array of vetted strategies (Grant et al., 2013).

In particular, Melbourne is setting an example of how to drive transformational change across the region's urban water management framework. After the Millennium Drought, Melbourne began closely collaborating with water agencies, stakeholders and the wider community in order to transition to a whole-of-water-cycle approach to water management. This approach strives to holistically manage the entire water cycle system related to water supply, wastewater, rainwater, stormwater, roads, waterways and open space. It aims to ensure that decisions are made that consider the interconnectedness between elements of the urban water cycle to achieve shared benefits. Melbourne's governance and decision making involves many different stakeholders and agencies, and operates across a range of geographical scales and timeline. For example, in the whole-of-water-cycle framework that Melbourne currently uses, Melbourne Water, the three water corporations (Yarra Valley Water, City West Water and South East Water), a local government representative (one from each local government represented), the Metropolitan Planning Authority, and Parks Victoria sit on a governing body and interface with all stakeholders involved in a given project. This ensures that all stakeholders and appropriate water management authorities work together to develop projects - rather than in isolation - in order to maximize shared benefits (OLV, 2014).

Multi-Benefit Projects

Melbourne's approach to collaborative, whole-of-water-cycle management described above facilitates the construction of projects with multiple benefits. Traditionally, water projects are often heavily siloed and cater to only one component of the water cycle, such as conveyance channels for stormwater runoff. However, by incorporating multiple stakeholders and agencies early on in the design process, water projects are designed holistically to integrate different components of the water cycle into their construction. These multi-benefit projects allow for costs to be shared between agencies, alleviating the burden that traditional 'one-off' projects have on an agency's capital expenditures.

For example, Melbourne's Yarra Park Recycled Water Facility treats sewage leaving the Melbourne Cricket Grounds to recycled water standards, and then irrigates the surrounding landscape with the recycled water. The project produces approximately 47.6 million gallons of recycled water annually, and reduced the Melbourne Cricket Grounds' potable water consumption by 50 percent. Expenses for the project totaled $24 million AUD and were split between the Melbourne Cricket Grounds and the Australian Government (ARUP, 2014).

3. Alternative Water Sources can Increase Water System Resiliency.

Adelaide and Melbourne employed a mix of alternative strategies related to wastewater recycling, managed aquifer recharge, rainwater harvesting, and stormwater capture during the drought. Critical to the success of these strategies were statewide performance targets (e.g., the Victorian government set a statewide target to reuse 20% of all wastewater outflows to its treatment plants by 2010; South Australia set a target of 45% by 2013), and tight regulation around water quality and protection of public health (Grant et al., 2013). The governments of South Australia and Victoria mandate that water be treated only to the standard necessary for its intended end use, an approach referred to as 'fit for purpose.' Under this approach, rainwater that is plumbed indoors for flushing toilets and other non-potable uses does not have to be treated to drinking water standards, saving potable water and energy. Both governments have developed a comprehensive regulatory framework that covers virtually all reuse options with specific guidelines, including general recycled water use, on-site reuse, recycled water dual-pipe (purple pipe) development, direct stormwater reuse (including rainwater harvesting), and managed aquifer recharge with recycled water and stormwater (Grant et al., 2013).

The following describes alternative water sources that Melbourne and Adelaide utilized to maximize potable water during the Millennium Drought.

Managed Aquifer Recharge:

Managed aquifer recharge is the process of infiltrating or injecting water into aquifers under controlled conditions for withdrawal at a later date. South Australia began employing this practice to address a long-term downward trend in groundwater levels caused by increasing water demand from development and agriculture. Managed aquifer recharge techniques can also be used as a barrier to prevent saltwater or contaminants from entering the aquifer, as is done in southern California with recycled water. Adelaide and the nearby city of Salisbury have tested managed aquifer recharge strategies since the early 1990s, and currently use urban stormwater to recharge aquifers to create freshwater reserves that are used for irrigation and non-potable water supplies for industrial and domestic uses.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) is leading several long-term managed aquifer recharge research studies to identify the most effective applications for using this approach to augment and improve local water supplies[1]. Among the managed aquifer recharge methods being tested are: aquifer storage and recovery (ASR) – the recharge of an aquifer via a well with subsequent recovery from the same well; and aquifer storage transfer and recovery (ASTR) – the recharge of an aquifer via a well for subsequent recovery from another well, to allow a minimum residence time in the aquifer before recovery. In particular, a recent CSIRO study (Page et al., 2014) has shown that water moving through an aquifer in ASTR schemes undergoes enhanced microbiological treatment that removes a substantial number of pathogens. This water could then be used for a variety of end uses, such as irrigation, domestic and industrial non-potable reuse, and drinking water, with additional treatment.

[1] CSIRO is the federal government agency for scientific research in Australia.

Stormwater Capture and Reuse

Both Melbourne and Adelaide employed stormwater capture and reuse strategies to provide alternative water sources for nonpotable purposes. This reduced demand for potable water and provided a fit-for-purpose approach to water supply, treating water only for its intended end use. Water sensitive urban design projects were common responses to the drought, and many projects were built to capture stormwater runoff from a given catchment area, store captured water in tanks for a later date, and then reuse the water for irrigation.

In Melbourne, for example, the Royal Botanic Gardens Working Wetlands Project is designed to rehabilitate lakes suffering from diminishing water volumes and declining quality. Stormwater runoff is diverted from surrounding streets into the wetlands, treated through floating islands, circulated through a series of lakes and finally stored in large tanks. Once stored, the treated water is available for irrigation. This approach allows urban runoff to be viewed as a resource, creating a steady demand for non-potable water.

The City of Los Angeles has designed similar projects, including its Proposition O-funded rehabilitation projects at Echo Park Lake and Machado Lake. The Melbourne project differs notably in the inclusion of storage tanks as an additional component that extends the project's function beyond water quality management and into water supply provision. This example may provide a viable model for restoring urban water bodies while addressing runoff, water quality and localizing supply.

Rainwater Harvesting

Most Australian cities have a culture of rainwater harvesting (RWH), partly because many urban residents are still connected to their outback roots where RWH was for a very long time (and in many cases still is) the only water supply. The drought reawakened interest in RWH and increased demand for the practice within Adelaide and Melbourne, as well as in other cities, both for potable and nonpotable uses. Water managers found that the concept of RWH was very popular with ratepayers, in part because severe water restrictions banned the use of potable water for household outdoor landscaping. As a result, the public demanded incentives for RWH tanks and equipment, which effectively gave agencies a mandate to invest in RWH programs. By the end of the drought, rainwater tanks were present in 30% of Melbourne households and ~50% of Adelaide households (City of Melbourne, 2014a; SA Water, 2014).

The best example of RWH in Australia comes from Adelaide, which, alongside neighboring towns, has the highest percent of tank ownership in Australia. Adelaide is at the mouth of the Murray-Darling River Basin, which drains much of Southeast Australia, including large portions of Queensland, New South Wales, Victoria, South Australia and all of the Australian Capital Territory. Water quality has long been of poor quality at the mouth of the basin, and many Adelaide residents trust rainwater captured off their roofs more than they do river water or groundwater. In fact, many residents use rainwater for potable purposes including cooking, drinking and washing.

‘Right Water’ Campaign

In 2014, Victoria launched the ‘Right Water’ campaign geared towards encouraging households to make greater use of alternative water sources. The initiative incentivizes the installation of rainwater harvesting cisterns and rain gardens by showing the expected water bill decreases that would result from using less potable water. For example, it is estimated that every year Melbourne households have approximately $200 - 400 AUD worth of water fall on their roofs (Victorian Government, 2014). During the policy delegation, this campaign was immensely popular and advertised heavily on billboards, print, trams, and during major events, with pop-up tents staffed with employees giving demonstrations on how to install rain tanks and rain gardens.

4. Balancing Water Scarcity Planning with Other Needs.

Climate Change and Adaptation

Extreme heat events in January of 2009 - the last year of the Millennium Drought - caused a 62% mortality increase in the City of Melbourne, resulting in 980 deaths (Norton et al., 2015; Victorian Government, 2009). Temperatures during this time were 22 - 31 degrees Fahrenheit higher than normal throughout Victoria (the average January temperature in Melbourne is ~70 degrees Fahrenheit), and Melbourne saw three consecutive days of temperatures exceeding 109 degrees Fahrenheit (Victorian Government, 2009). By this point in the drought, water restrictions banning the irrigation of public spaces had substantially reduced vegetation - and shade - and the urban heat island effect greatly exacerbated the heat wave. These extreme heat events are only expected to get worse in the future, and climate change is forecasted to increase the frequency, intensity, and duration of such events (Norton et al., 2015). Melbourne is addressing this issue by increasing the amount of urban green spaces located throughout the city to cool the system. These urban green spaces are watered using non-potable, fit-for-purpose water from stormwater harvesting and recycled water projects.

Water for Livability

The City of Melbourne focused the first iteration of their whole-of-water-cycle efforts narrowly on water security and water conservation efforts. These efforts were effective, but when the city stopped watering - or put limits on watering - sports fields and public green spaces, recreational activities stopped or were severely curtailed. The hardened ground caused injuries, and many sporting events were cancelled. Also, the public psyche was negatively impacted as residents witnessed the city’s historic botanical gardens and public green spaces turn brown, and long-term urban heat island mitigation benefits from vegetation were reduced (Norton et al., 2015). While these drought restrictions were imperative on a citywide scale, the city learned a critical lesson: that special attention must be paid to keeping public green spaces green, even during severe droughts.

Water for the Environment

During the Millennium Drought, the environmental flow entitlements given to the Yarra River were quickly reallocated to the City of Melbourne when water restriction were in place. These legally mandated environmental flow entitlements were suspended from the time of their publication in 2007 until water restrictions eased in 2010. The Victorian Government justified this decision by estimating that the suspension of environmental entitlements to the Yarra River provided an additional 120,000 AF of water (or five months of urban supply) and avoided the need to introduce more severe water use restrictions (Grant et al., 2013). However, decreased environmental flows to the Yarra River were devastating, and resulted in the acidification of lower lakes, dying floodplain forests, loss of habitat for native species, the degradation of water quality, and multiple sensitive species at risk of extinction. These damages are still being felt, and the city has spent millions of dollars trying to restore and rehabilitate the river to its pre-drought conditions.

This example illustrates the need for robust environmental flow requirements during periods of water scarcity. While eliminating environmental flows during the Millennium Drought provided the city with additional water, the negative environmental consequences and extreme cost provides proof that environmental flows need to be prioritized during times of water scarcity. Today, Victoria is the fourth largest holder of water in the state, and stringent environmental flow standards ensure that water is available to sustain critical riverine ecosystems, even during periods of extreme drought.

Total Watermark: City as a Catchment Plan

To address the issues described above, Melbourne created Total Watermark: City as a Catchment, a $50-million (AUD) 2010-2015 whole-of-water-cycle plan that looks at using water in four specific areas:

- *Climate Change and Adaptation* - A resilient and safe city that is adapted to current and future extreme weather events.
- *Water for Liveability* - A water cycle that supports the health, well-being and enjoyment of everyone who lives, works, visits and plays in Melbourne.
- *Water for the Environment* - Water that is managed for biodiversity, healthy public open spaces and clean waterways.
- *Water Use-* Efficient use of fit-for-purpose water contributes to Melbourne's improved sustainability.

One of the drivers behind this planning strategy is to create "a city in the forest, rather than a forest in the city," by focusing on extensive urban forestry efforts. The city plans to increase urban tree plantings in order to double canopy cover, increase green space, increase permeability, increase stormwater harvesting, and cool the city by 7.2 degrees Fahrenheit. Measurements taken during extreme heat events in Melbourne suggest that a 10% increase in vegetation cover could reduce daytime urban heat temperatures by approximately 1.8 degrees Fahrenheit (Coutts and Harris, 2013).

Non-potable water is used to irrigate these new plantings, as water-stressed vegetation has both higher surface temperatures and reduced rates of plant transpiration in comparison with irrigated vegetation (Norton et al., 2015). Because non-irrigated landscapes greatly intensify urban heat island impacts, the city sees it as imperative to plant and irrigate landscapes that are capable of absorbing heat. Special emphasis is being placed on retrofitting the city's road networks with green infrastructure and urban trees, as this presents the dual benefits of reducing the amount of heat emitted from asphalt, and also by capturing large volumes of stormwater. In an average year, Melbourne's stormwater runoff greatly exceeds demand, and the city is implementing numerous stormwater harvesting projects to capture this untapped water source. In addition to supplementing water supply, stormwater capture and reuse projects also provide numerous ecosystem services, such as restoring predevelopment flow regimes and retaining nutrients and pollutants in a catchment. In 2015, 57 stormwater capture and reuse projects are estimated to be in operation in Melbourne (Grant et al., 2013).

5. Public Behavior Change around Water Conservation

The drought fostered a vibrant culture of Australian residents taking responsibility as water managers. This was accomplished most effectively through a mixture of efforts related to public education, target setting, social comparisons, water restrictions, efficiency labeling, rebates, and water pricing. Daily per capita water use was reduced substantially for residents of both Adelaide and Melbourne, and by the end of the drought Adelaide averaged 60 gallons per person per day, and Melbourne averaged 65 gallons per person per day (Grant et al., 2013; Maier et al., 2013).

In particular, the City of Melbourne implemented an aggressive 'Our Water Our Future' water conservation campaign from 2002-2010 geared towards changing residents' behavior around water use. This conservation campaign focused on three main areas - water literacy, valuing water, and motivating action - with the goals of reducing individual and corporate water use; changing individual behaviors; and creating positive attitudes towards water restrictions and increases in water pricing. To implement this plan, Melbourne utilized all of the behavior change tools available, including changing social norms, financial incentives, social marketing, regulation, community engagement (e.g. "Right Water" campaign), and innovation. The city provided daily water levels for each reservoir on the front page of the newspaper; drought workshops were held frequently to engage the local community; per capita water consumption targets were set (e.g., Yarra Valley Water's "Target 155 Liters" campaign); and water users were compared with their neighbors to inspire reductions in use.

The campaign was enormously effective, and resulted in a 45 percent reduction in water use in 2010 compared to the 1990s (Thwaites, 2014). Because long term average stream inflows plummeted by as much as 55 percent during the Millennium Drought, without water conservation the Melbourne's reservoirs would have run dry by July 1, 2009 (see Figure 4) (Thwaites, 2014). Important take home messages from this campaign show that when dealing with complex long-term issues like behavior change, political leadership and community engagement are critical to creating an environment receptive to change. Further, additional

lessons show that user motivation is inspired by emotion, and that behavior change campaigns need to be implemented early on during a drought due to their long incubation times.

The following describes some of the strategies used by both Melbourne and Adelaide to facilitate a behavior change around water conservation:

Coordinated Mass Media Public Education:

The City of Melbourne implemented a large-scale mass media advertising campaign via TV, radio, print, billboards, and community events that saturated the market and dramatically increased awareness of the ongoing drought. The campaign's messaging was clear and concise, with motivation stating that residents needed to pull together to get through the drought; reminders that water restrictions were in effect; and current information regarding the amount of water available in reservoir storages. The campaign was enormously successful, and its efficacy was continually gauged through sampling surveys and phone interviews with customers. The total cost of advertising during the drought was estimated to be around $8 million (AUD), with Melbourne Water contributing approximately $6 million, and City West Water and Yarra Valley Water contributing $1 million each.

Aggressive Water Consumption Targeting:

In Melbourne, Target 155 Liters was a voluntary initiative implemented as a result of a task force finding to set aggressive targets for residential water consumption. The target urged water consumers to use 155 liters (40 gallons) or less per day, and was extremely effective in changing consumers' attitudes and behaviors towards water conservation. Target compliance became a badge of honor for the public, and a new social norm around water consumption developed. Weekly reports comparing Melbourne's water use to Target 155 were delivered via the media, and achievement of the goal resulted in intensive coverage in print, television, and radio outlets. Today, Melbourne has revised these standards to Target 130 Liters in the winter, and Target 190 Liters in the summer.

Smart Water Bill:

Yarra Valley Water, one of Melbourne's water retailers, redesigned its traditional water bill to a new 'Smart Water Bill' - an informative, easy-to-read bill that indicates how a household is fairing compared to both normal and water-efficient households. The bill uses both descriptive and injunctive norms to adjust users' perception of 'normal' water use, and then further encourage them to conserve. Research conducted by Yarra Valley Water indicates that the Smart Water Bill was tremendously effective in changing users' behavior towards water, as most water users did not actually know how much water they were using. The Smart Water Bill also contains water efficiency tips and rebates, and shows the progress that users are making towards achieving Melbourne's current water conservation targets.

Water Restrictions

Water restrictions in both Melbourne and Adelaide had a tremendous impact on public behavior as parks began to turn brown and public fountains were turned off. Further, deputized "inspectors" and meter readers wearing patrol vests were common and helped the public remember that water restrictions were in place. Water fines for non- compliance were typically between $100 - $500 (AUD) and were not issued until the second or third offense (Gleick et al., 2012). However, as most restrictions were difficult or impossible to enforce, the high compliance with water restrictions was most notably due to the cooperation and goodwill of the public. Australians generally had a "we're all in this together" attitude and were highly supportive of the water restrictions (Gleick et al., 2012).

Water Efficiency Labeling Standards

In 2006, Australia implemented the Water Efficiency Labeling Standards (WELS) program to provide a uniform set of standards promoting water-efficient appliances and fixtures. The WELS program requires faucets, showers, toilets, urinals and flow controllers, clothes washers, and dishwashers to be labeled according to their water efficiency. In addition, the program also provides product testing and the enforcement of required standards. The United States Environmental Protection Agency's WaterSense Program is modeled on WELS; however, WaterSense is a voluntary program and not a required standard for appliances and fixtures (Gleick, 2012).

Water Conservation Rebates and Appliance Retrofits

Beginning in 2003, water conservation rebates were provided by the Victorian Government for a range of water saving products and services, such as rainwater tanks, shower heads, greywater systems, dual flush toilets, dishwashers, washing machines, and water conservation audits. These rebates were allocated in four year cycles based on drought severity and forecasted demand. Rebates generally focused on the large consumers of residential water in the home, targeting single flush toilets first. Today, dual flush toilets are mandatory for all households.

Water Pricing

Among the many reforms passed during the Millennium Drought, the National Water Initiative created a set of nationwide principles for pricing urban water. These guidelines require utilities to put water rates for all types of customers on a rational footing, removing political pressure to underprice water as a means to win favor with voters (Gleick et al., 2012). Both Melbourne and Adelaide were forced to raise water rates during the drought, and the rate increases had the dual objectives of signaling the scarcity of water, and helping pay for the major investments in water supply infrastructure. In Melbourne, a 5% environmental levy was implemented in addition to a modification of the block tariff structure from two to three tiers (Grant et al., 2013). In Adelaide, block prices were nearly doubled in comparison with pre-drought levels (Maier et al., 2013).

Policy Recommendations

The following policy recommendations are based on the key themes that emerged over the course of the policy delegation in Adelaide and Melbourne. These policy recommendations provide both short and long-term solutions that can help California address the ongoing drought and the water crisis.

1. Transition towards Whole-of-Water Cycle Management

Increase Local Agency Collaboration and Transition to Whole-of-Water-Cycle Management to Facilitate Multi-Benefit Projects

Fragmented southern California water management systems need to begin transitioning towards a whole-of-water-cycle approach to water management. The Los Angeles region offers an example of how this transition might occur. TreePeople's latest report, *Moving Towards Collaboration: A New Vision for Water Management in the Los Angeles Region* (2015), summarizes findings and recommendations to increase collaboration between the City of Los Angeles Bureau of Sanitation, City of Los Angeles Department of Water and Power, Los Angeles County Department of Public Works, and TreePeople. This Multi-Agency Collaborative (MAC) initiative builds a case for a collaborative, systemic approach to address the region's short-term drought emergency and long-term water crisis. Key findings from the report include the following:

- The Los Angeles region stands to benefit from creating a shared vision, defined goals, and coordinated strategy that is managed across agencies through mutually reinforcing activities.
- There is a unique and unprecedented opportunity to make critical and rapid shifts to our local water management systems due to the current financial, regulatory, and political environments. Various factors, including the drought and new water quality regulations, provide an incentive for the region's largest infrastructure agencies to work together to meet their discrete, yet overlapping, goals.
- Annual stormwater costs to the City agencies and County are projected to increase to at least $2B annually – or six times the existing costs. With this expected increase, the efficiencies of working together become even more critical, and further the value of a more collaborative management approach for Los Angeles.

This approach emphasizes how, within current water management frameworks, agencies can establish shared goals, systems, and agreements to increase efficiency and collaboration. For more information on the MAC and the Systemic Collaboration approach, please find *Moving Towards Collaboration: A New Vision for Water Management in the Los Angeles Region* here.

Create a Cost-Benefit / Co-Investment Tool to Quantify Water Supply, Water Quantity and Other Benefits to Increase Collaboration Across Fields

A robust, inter-agency and inter-jurisdictional cost-benefit tool should be created that clearly quantifies water supply, water quality, and other benefits related to southern California's water projects. Without this type of agreed upon tool or model, it is difficult to attribute benefits to any particular sector, or agency. It is therefore difficult to make the case for co-investments that could make alternative water supply projects - like stormwater capture and reuse - more economically feasible. Current planning occurs using a single-purpose cost-benefit approach - in essence, the costs and benefits to that one agency. This can lead to decisions that rule out certain multi-benefit projects if costs and benefits are not identified for other agencies (and potential investors) (TreePeople, 2015).

2. Encourage Alternative Water Sources

Set Aggressive Targets for Stormwater Capture and Reuse, Rainwater Harvesting, and Wastewater Recycling

Water management agencies throughout southern California should set aggressive volumetric and substitution targets to increase: a) the volume of stormwater captured and reused throughout the region; b) the volume of rainwater harvested and reused throughout the region; and c) the volume of wastewater recycled (as a percentage of total wastewater; for example, Melbourne set targets to reuse 20% of all wastewater flows to its treatment plants by 2010). By setting aggressive targets, the region can actively form initiatives and policies to achieve the stated goals. This was instrumental in helping Melbourne develop alternative water sources during the Millennium Drought, and one of their key lessons learned.

Los Angeles has already been begun to set targets, with Mayor Garcetti issuing an executive directive to reduce potable water use by 20 percent by 2017, and also to reduce the Los Angeles Department of Water and Power's purchase of imported water by 50 percent by 2024. Further, progress is beginning to be made with stormwater capture and reuse, with initial results of the Los Angeles Department of Water and Power's Stormwater Capture Master Plan indicating that Los Angeles could capture between 30 - 45% of the city's current water demand with the right infrastructure, programs, and policies in place (LADWP, 2014). As initiatives like the Stormwater Capture Master Plan begin to be further developed, assigning volumetric and substitution targets can help the city put the right programs and policies in place to achieve their goals.

Ban the Use of Potable Water to Irrigate Outdoor Landscaping and Focus on Incentivizing Alternative Water Sources in New Development

New policies should be put in place in southern California that ban the use of potable water for outdoor irrigation in new development. Currently, water used to irrigate outdoor residential landscaping constitutes the single largest end use of urban water, accounting for 34% (3.0

million acre feet) of total urban uses in the state (DWR, 2013). Much of this potable water is used to irrigate cool-season, water thirsty turf grasses that are most often planted exclusively for ornamental value. Policies should focus on banning potable water used for irrigation in new development, providing incentive for climate-appropriate plantings (climate-appropriate planting utilize around 75% less water than turf) and alternative water sources. This can help to increase household alternative water sources - such as rainwater harvesting and graywater systems - throughout the region.

Provide Incentives and Rebates for Water Efficient Appliances, Rainwater Harvesting Systems, and Graywater Systems

Water rebates and incentives should be streamlined throughout southern California to encourage the adoption of water efficient appliances and fixtures. Although many state water retailers and water districts currently offer rebates for high efficiency clothes washers, high efficiency toilets, rotating nozzles, irrigation controllers, and rain barrels, more can be done, especially with regard to rebates for graywater systems and larger rainwater cisterns. By offering rebates for rainwater cisterns and graywater systems, non-potable water can be provided for outdoor landscaping irrigation, and local water supplies can be further developed.

3. Integrating Water Scarcity with Climate Adaptation Planning

Set Aggressive Regional Cooling and Tree Canopy Targets

Cities and counties throughout southern California should set regional cooling and tree canopy targets to reduce the impacts of the urban heat island effect. As urban populations grow and are pushed beyond their adaptive capacity to deal with extreme heat events, higher rates of mortality and morbidity ensue. Measures need to be taken to increase urban green space and vegetation in order to cool the urban system. Increasing green space by 10% can reduce daytime urban heat temperatures by approximately 1.8 degrees Fahrenheit, and additional benefits - such as increased stormwater capture, public recreation spaces, and improved air quality - can result (Coutts and Harris, 2013)

Create Guidance to Protect Livability and Health When in Drought Situations

Cities and counties throughout southern California should implement policies to ensure that public green spaces are irrigated with non-potable water during times of drought. Melbourne's experience shows that recreation and public psyche are dependent on public green spaces, as these areas offer critical respite from both the stresses of urban life and the urban heat island effect. Southern California needs to ensure that it maintains its public green spaces, even during times of water scarcity.

Increase Locally-Sourced Supplies to Ensure that Environmental Flows are Met in California

Cities and counties throughout southern California need to increase locally sourced water supplies to ensure that the water it imports is not interfering with minimum environmental flow standards in California's river basins. California is currently struggling with how to manage environmental flows during extreme drought. For example, 2014 saw 95% of the Sacramento River's annual Chinook salmon winter run lost due to warm water temperatures killing eggs and recently hatched fish. Because Lake Shasta was drawn down to its second-lowest level on record, it did not have the capacity to release the cold-water environmental flows necessary to sustain salmon populations. Lake Shasta provides water that is utilized throughout southern California via the State Water Project, and water conservation efforts throughout the state can help to increase the amount of water available for environmental flows.

4. Public Behavior Change around Water Conservation

Create an Integrated, Clear and Consistent Messaging Campaign

Southern California water management agencies need to create a clear and consistent water conservation campaign that spans across jurisdictional boundaries. This campaign should be issued through TV, radio, print, billboards, and community events, and implemented over a sustained time frame. Water districts and wholesalers should contribute significant funding to the campaign as part of their water conservation efforts.

Increase the Cost of the Non-Essential Use of Water

Water retailers throughout southern California should continue to pursue increasing block tariffs as a way to curb the consumption of heavy water users while still protecting low-income customers. Increasing block tariffs provide a buffer zone between the low rates required for low-income customers and the high rates required to dissuade heavy water users (McKenna and Song, 2014). While many water retailers have implemented increasing block tariffs throughout southern California, efforts should continue towards implementing tiers that drive down excess water use.

It is worth noting that Proposition 218 - a voter-approved measure that prohibits government agencies from charging more for a service than it costs to provide it - currently stands as a significant obstacle in implementing increasing block tariffs. A recent decision by the 4th District Court of Appeal rendered the City of San Juan Capistrano's increasing block tariff structure illegal due to violation of Proposition 218. Although this decision will undoubtedly become challenged in the near future, water retailers need to ensure that they have the appropriate data in place to justify a decision to change their rate structures.

Deliver Social Comparison of Water Consumption

Southern California utilities should work with researchers or third parties to deliver social comparisons of household water consumption patterns. Normative comparisons have been shown to be tremendously effective in reducing water use when messaging is sustained over time (McKenna and Song, 2014). These normative comparisons can be delivered via a bill or through an independent study.

Set Aggressive Water Consumption Targets

Regions throughout southern California should implement per-capita water consumption targets. Although the California State Water Resources Control Board has required the municipalities reduce their water consumption by 20% in comparison to 2013 levels, more can be done to increase water conservation at the individual person scale. Similar to Melbourne's Target 155 Liters campaign, these individual targets should be voluntary and heavily advertised to increase awareness of both per-capita water use and water conservation. Targets should be set for both winter and summer, and should be based on realistic metrics that are attainable for residents

Conclusion

Archaic water policy, fragmented water governance, and single-purpose water projects have resulted in much of southern California's potable water being squandered during times of water scarcity. However, as reservoir levels continue to drop and the current drought continues to make history in terms of severity, the state's residents are beginning to see the flaws of the existing water management system. Southern California now has a rare opportunity to galvanize the public around water scarcity issues and implement transformative water policies that will set the state on a path towards sustainability and climate resiliency. The lessons learned from Melbourne and Adelaide offer key insight into how southern California cities can best respond to water scarcity issues in order to maximize potable water supply, mitigate urban heat island effect, protect water bodies and wildlife, and ensure that water is available in the future. These lessons need to be realized through the policy recommendations outlined in this report, and doing so can continue to make southern California a world leader in innovation and progression. In the future, a re-imagined southern California water system will have the following components:

- Efficient, Fit-for-Purpose-Water used to Irrigate Landscapes;
- Agencies that Collaborate Together and Implement Projects with Multiple Benefits;
- Healthy Waterways that are Protected by Robust Environmental Flow Regulations;
- Dense Urban Forests that Mitigate Heat and Provide Stormwater Capture; and
- A Water-Wise Public that Uses Water Efficiently.

These re-imagined components are the skeleton of a new southern California water system that will be able to address the water scarcity issues of today and the future. California water leaders

need to start taking steps towards these goals and leverage the rare window of opportunity they are currently afforded.

Appendices

Appendix A: List of Semi-Structured Interviews

California Interviews			
Person	**Position**	**Organization**	**Expertise**
Edith Deguzman	Director of Research	TreePeople	Decentralized Water Management
Deborah Weinstein	Director of Policy	TreePeople	Collaborative Governance and Recycled Water
Andy Lipkis	Founder	TreePeople	Decentralized Water Management and Collaborative Governance
Richard Ambrose	Professor	UCLA – PIRE Grant	Decentralized Water Management
David Feldman	Chair of Planning	UCI – PIRE Grant	Collaborative Governance and CA Water Policy
Sayd Randle	PhD Researcher	Yale	Decentralized Water Management and Recycled Water
Brandon Winfrey	Post Doc Researcher	UCLA – PIRE Grant	Decentralized Water Management
Vjeko Matic	PhD Researcher	University of Melbourne	Groundwater Management
Jared Blumenfeld	Administrator	EPA Pacific Southwest Region	Southwest Water Management
Andrew Fahlund	Deputy Director	CA Water Foundation	CA Water Policy
Leslie Friedman – Johnson	Principal	LFJ Strategies	CA Water Policy
Felipe Fuentes	Councilmember	LA City Council	CA Water Policy
Greg Good	Director of Infrastructure	City of Los Angeles	LA Water Projects

Gary Hildebrand	Assistant Deputy Director	LA County Department of Public Works	LA Water Projects
Felicia Marcus	Chair	CA State Water Resources Control Board	CA Water Policy
Traci Minamide	Chief Operating Officer	LA Bureau of Sanitation	LA Water Projects, Decentralized Water Management, and Recycled Water
Nancy Sutley	Chief Sustainability Officer	LA Department of Water and Power	LA Water Projects
Francesca Vietor	Commissioner	SF Public Utilities Commission	CA Water Policy
Melbourne, Australia Interviews			
Person	**Position**	**Organization**	**Expertise**
Brandon Winfrey	Post Doc Researcher	UCLA – PIRE Grant	Decentralized Water Management
Andy Lipkis	Founder	TreePeople	Decentralized Water Management and Collaborative Governance
Deborah Weinstein	Director of Policy	TreePeople	Collaborative Governance and Recycled Water
Vjeko Matic	PhD Researcher	University of Melbourne	Groundwater Management
David Feldman	Chair of Planning	UCI – PIRE Grant	Collaborative Governance and CA Water Policy
Edith Deguzman	Director of Research	TreePeople	Decentralized Water Management
Ray Beaton	Water Resource Strategy Manager	Yarra Valley Water and the Office of Living Victoria	Collaborative Governance
Helen Delaporte	Water Efficiency	Victoria Department	Water Conservation

	Manager	of Sustainability and the Environment	and Efficiency
Les Walker	Project Manager, Schools Water Efficiency Program	Victoria Department of Sustainability and the Environment and the Office of Living Victoria	Water Conservation and Efficiency
Deni Warwick	Program Associate	Office of Living Victoria	Water Conservation and Efficiency
Adelaide, Australia Interviews			
Bruce Naumann	Manager, Managed Aquifer Recharge Projects	Salisbury Water	Managed Aquifer Projects
Steve Morton	Manager, Urban Water, Economics and Water Security	South Australia Department of Environment, Water, and Natural Resources	Australian Water Policy and Urban Water Management
Mark Wilson	Senior Manager, Business Development	SA Water	Business Development and Water Policy
Chris Egan	Trade Development Officer	UK Trade and Investment	Water Policy
Jacqueline Frizenschaf	Manager, Naturak Assets	SA Water	Decentralized Water Management

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