Water in the time of drought

Lessons from five droughts around the world

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WATER IN THE TIME OF DROUGHT

Lessons from five droughts around the world

"IT'S WHEN THE WELL IS DRY THAT WATER BECOMES WEALTH. "

French proverb

« C'EST QUAND LE PUITS EST SEC QUE L'EAU DEVIENT RICHESSE. »

Proverbe français

TABLE OF CONTENTS

INTRODUCTION

From Brazil to the United States to Australia, climate change is increasing the frequency and severity of droughts, presenting policy makers water and sanitation utilities with formidable challenges:

- In São Paulo, South America's largest city and home to 20 million people, elevated temperatures and lack of rains in 2014 caused the worst water crisis in over 80 years. Even today, the key Cantareira reservoir system is supplying less than half the water it provided before the drought started.

- In California, 2012 marked the beginning of a five-year drought that put severe strain on the state's water supply, leading Governor Jerry Brown to declare a drought emergency in 2014. State authorities also imposed major restrictions on urban water suppliers and outdoor water use. The situation was so severe that the San Francisco Public Utilities Commission adopted restrictions of its own on top of those mandated by the state government and the impact on agriculture state-wide was devastating, with nearly US $2 billion in direct losses.

- In Australia, the Millennium Drought, a drought that lasted from 1997 until 2012, presented both a crisis and an opportunity to innovate. With respect to the latter, the government rolled out new water savings initiatives and incentives, and leveraged 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.

This policy brief examines these crises, explores successes and pitfalls in the response mechanisms, and extracts valuable lessons to assist decision makers in dealing with droughts, providing practical guidance in terms of urban planning and management.

It will do so through a three-pronged approach: First, it describes the situation each utility and region faced while tackling the drought, as well as the measures they implemented to respond to that dire situation. Second, it will present some recommendations and lessons learned to build climate resilience in the future. Lastly, it will show how droughts may often be catalysts for new strategic measures and innovation that address water stress over the long term.

Note: The cases featured in this brief were selected in terms of availability of information to illustrate the policies and lessons learned identified as key for water utilities.

SÃO PAULO, BRAZIL


Aerial view of a multi-lane highway crossing the Atibaina Reservoir near the town of Nazare Paulista. The reservoir is part of the Cantareira system (the largest system of public water supplies in Latin America) which provides fifty percent of São Paulo's drinking water.

The city of São Paulo, like other highly populated urban areas, faces numerous challenges in providing water security given its rapidly growing population and declining water availability. The Metropolitan Region of São Paulo (MRSP) has 39 municipalities, including the city of São Paulo itself. The metropolitan area's population has skyrocketed from 300,000 in the early 1900s to 21.3 million in 2016. The MRSP has low groundwater water availability in the Upper Tiete river basin, which makes it highly dependent on surface water sources (Rodrigues et al., 2015). The city is Brazil's economic powerhouse—with 10% of the national population, the MRSP accounts for 19% of the national GDP. Meanwhile, water demand increased from 5m3/s in 1940 to 71.4 m3/s by early 2014 (Hermann and Braga, 2015). While this was also dramatic growth, it was badly outpaced by the demographic boom, generating water shortages. In response to this situation, a water transfer project from the Piracicaba River basin to supplement supply to the MRSP was launched in 1966. Construction of the Cantareira system was completed in 1973 and involved building four dams in the Piracicaba and Upper Tietê River basins (Rodriguez et al., 2015).

THE CANTAREIRA SYSTEM

Cantareira is the largest water source for the MRSP, supplying about half the area's demand, with the remaining supply coming from seven additional systems (SABESP, 2015). The São Paulo water utility, SABESP, serves the São Paulo Metropolitan Region through the production and transportation of potable water for about 20 million people in 35 municipalities. The Cantareira system consists of the Jaguari/Jacareí, Cachoeira, Atibainha, Paiva Castro and Águas Claras. (SABESP, -CHESS- Crise Hídrica, estrategia e Solucoes da SABESP, April 30, 2015). The Cantareira system involved the construction of four dams on rivers in the Piracicaba and Upper Tiete river basins (Rodrigues et al., 2015). The Cantareira system provides, under normal conditions, 33m3/s of water to 8.9 million people in the RMSP and 5m3/s to the downstream region of Campinas and Jundaithat (SABESP, 2015).

Faced with this very critical situation, SABESP has adopted a series of strategic measures, which resulted in a reduction of water withdrawal from the aquifers of Grande São Paulo of 30% – from 71 m³/s in January 2014 down to 50 m³/s in February 2015 (SABESP, -CHESS-April 30, 2015).

The Cantareira system was the most impacted by the drought and received the most attention, because it contributed to 56% of the production of the city's water supply - from 33 m³/s for 9 million people at the beginning of the crisis to 14 m³/s, in March 2015 (SABESP, -CHESS- April 30, 2015).

It is important to note that SABESP and other water utilities in the region do not have the authority to manage crude water proceeding from lakes and rivers. They cannot mandate the reduction of water consumption for irrigation, for instance. This is the responsibility of the National Water Agency of Brazil (ANA), the regulatory agency (SABESP, -CHESS-April 30, 2015).

CLIMATE CHANGE

Increased warming in the region occurring since 1961 is linked to a higher risk of droughts. Concurrently, vulnerability to water scarcity has been, and continues to be, aggravated by growing water demand due to population growth (Nobre et al., 2016). In fact, in terms of climate change adaptation, the most important issue in São Paulo is water, including policy measures to ensure the provision of water and multiple-use water systems, as well as a holistic approach in water use and management (ECLAC, 2014). In addition, awareness about limited freshwater resources needs to be raised in the MRSP to achieve sustainable development (Nobre et al., 2016). In this regard, with the purpose of improving water management in the municipalities in the State of São Paulo, the Secretariat of Environment (SEA) launched the Pacto das Águas in 2009 and significant goals have been accomplished since then (Cook et al., 2010).
The 2014-2017 Brazilian drought affected the southeast of Brazil the worst, including the metropolitan areas of São Paulo and Rio de Janeiro. Minas Gerais and Espiritu Santo were still being affected by the drought in 2016 due to the El Niño event. On May 5 of that year, the Espiritu Santo Government declared a state of emergency across the state as the drought worsened. At least 93 cities imposed rationing because of the severe drought. Agriculture was drastically impacted. Production of arabica coffee beans, a commodity that Brazil supplies in far greater bulk than any other country, fell 15% in 2014, pushing up the price of the commodity by almost half. Sugar and ethanol output were also impacted.

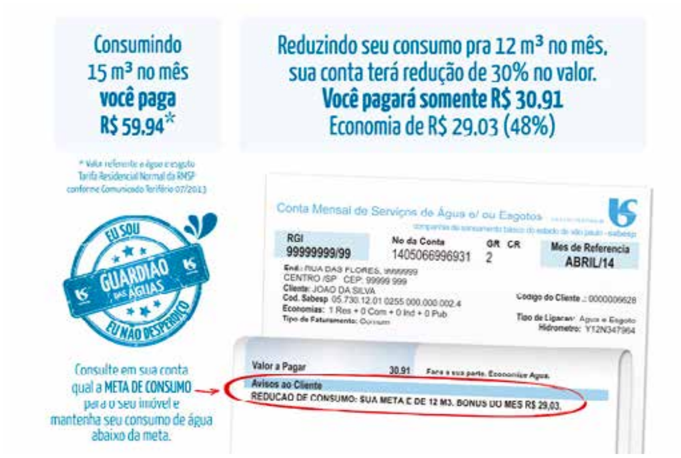
In February 2014, in response to the drought, the state governor created a Technical Advisory Management Group (GTAG) to determine how to operate the Cantareira system during the drought. GTAG included representatives from ANA, the Department of Water and Energy (DAEE) and SABESP. At the same time, a series of management actions were taken to reduce demand on the Cantareira system. SABESP also evaluated the different options to tackle that situation and structured a plan to reduce water withdrawn from the Cantareira system, which was based on three central points:

- Incentivize a reduction in water consumption among customers through the implementation of a Bonus Program;
- Transfer water treated from other production systems toward the Cantareira system;
- Intensify the water loss program, focusing specifically on a reduction in response time, expansion of sectorization, installation of pressure reduction valves and reduction of water pressure in networks.

REDUCTION OF WATER CONSUMPTION

In February 2014, SABESP instituted a bonus program in which consumers who reduced consumption by over 20% were eligible for a 30% discount on their water bill. The Bonus Program was made available to everyone served by the Cantareira system in February 2014, to all residents of the MRSP in April 2014, and to other municipalities served by SABESP in the Piracicaba, Capivari and Jaguari River basins in the Cantareira catchment area from June 2014 to December 2014. In October 2014, the Bonus Program became more flexible and customers who reduced water use by 10%-15% received a 10% discount, those who reduced by 15-20% received a 20% discount, and those who reduced their consumption by more than 20% received a 30% discount. This Bonus Program was promoted to the public via social media and traditional media, as well as through direct solicitation (SABESP, -CHESS-April 30, 2015).

Example of bonus program (link here)



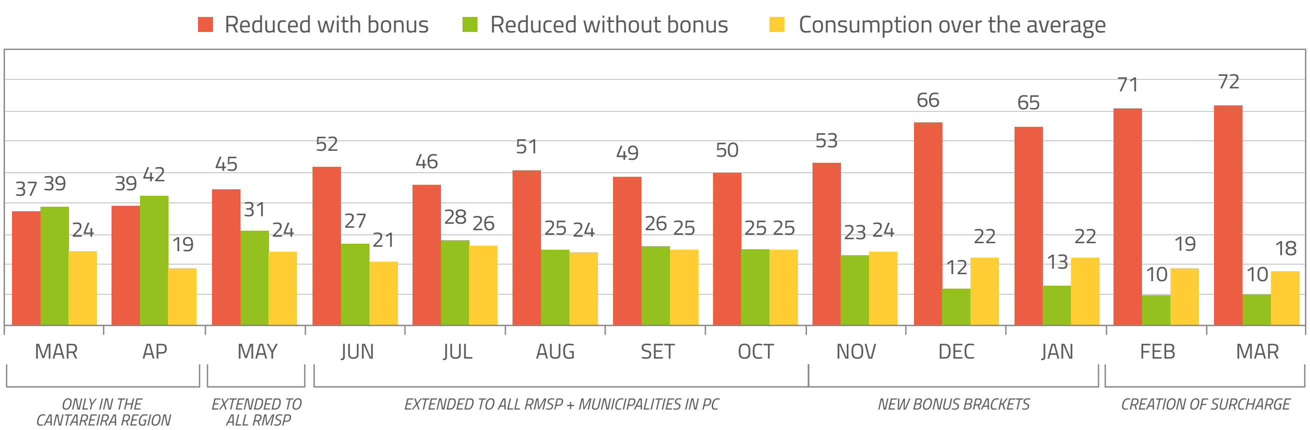
In February 2015, SABESP implemented a contingency fee for above-average consumption. Water consumption in the MRSP decreased from 155 liters per capita per day in February 2014 to 118 liters per capita per day in March 2015. SABESP penalized consumers who increased their water use by up to 20% by charging an additional 40% (contingency fee) and consumers who increased water use by over 20% by charging an additional 100%. (SABESP, April 30, 2015)

In January 2015, ANA, DAEE and the Secretariat of the Environment and Sustainable Development published a guide to water use restrictions. Residents reduced consumption through activities such as collecting rain and bath water and reusing wash water for watering plants, washing floors and flushing toilets. The timetable for the implementation of the program was as follows:

- 01/02/2014 Initiation of campaign. Only for region supplied by the Cantareira;
- 06/03/2014 Clients started receiving an invoice with bonus;
- 01/04/2014 Expansion of the program for municipalities operated by SABESP;
- 02/05/2014 Expansion of the program for municipalities operated by SABESP in the PCJ basin;
- 10/24/2014 Expansion of the bonus program (segment with 20% discount to those saving 15 to 20%; and segment with 10% discount for those saving 10 to 15%);
- 08/01/2015 Creation of a contingency fee for clients consuming above the fixed target;
- 09/02/2015 Clients started receiving an invoice with a contingency fee.

(SABESP, -CHESS-April 30, 2015)

Adherence to the program in the RMSP (in %)



Water savings obtained with the program (in m^3/s)

MAR	AP	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	JAN	FEB	MAR
1,1	**1,6**	**3,3**	**3,9**	**3,4**	**3,9**	**3,6**	**3,6**	**4,1**	**4,8**	**5,4**	**6,0**	**6,2**

As a result, 82% of MRSP clients cut their water consumption (72% of clients reduced consumption by more than 10% and obtained a bonus on their invoice, while 10% reduced consumption without receiving a bonus on their invoice (SABESP et al., April 30, 2015).

Additionally, 18% of clients had consumption above the average established in the program (11% were applied the contingency fee and 7% were not).

INTENSIFICATION OF WATER LOSS REDUCTION PROGRAM

The water loss program undertaken by SABESP is permanent and consists of large investments (USD1.5 billion based on exchange rate 1 = USD 0.31 as of 11/19/2017, with planned investments over the period from 2009-2020). To reduce leakages in pipes, pressure reduction valves were used to lower pressure in the distribution system. Together, these actions resulted in a reduction in water deliveries to the MRSP from 71.4 m^3/s in February 2014 to an average monthly production in 2015 of 52.0 m^3/s (SABESP et al., April 30, 2015).

Thanks to this program, water losses in São Paulo were reduced 1.2 percentage points each year over the past decade. The actions to tackle water losses (real and apparent losses) included:

- Installation of water pressure reduction valves;
- Water loss detection through acoustic methods;
- Rehabilitation or replacement of water pipes;
- Training and certification of labor;
- Sectorization of the water network; and
- Reduction of delays to attend water losses.

(SABESP et al., April 30, 2015)

Real water losses are technical losses whereas apparent losses are commercial losses. Real losses represented 62% of all water losses. The water loss program was the most effective program to tackle the drought, as it was responsible for 41% of the savings obtained in the Cantareira system (SABESP et al., April 30, 2015).

USE OF TECHNICAL RESERVES

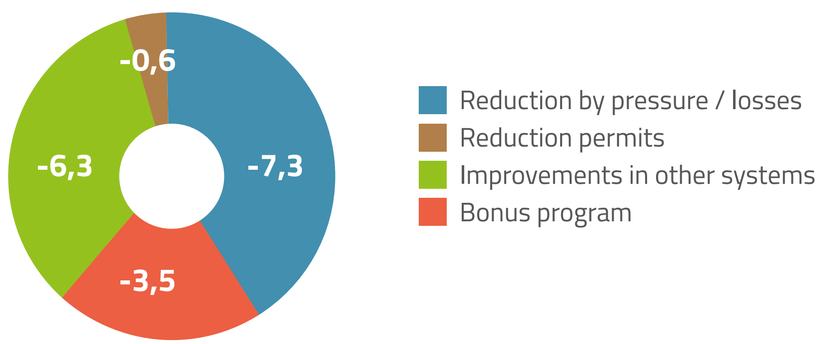
SABESP conceived the program to access 182.5 million m^3 of technical reserve from the Jaguari/Jacareí and Atibainha dams, called Technical Reserve I. Technical Reserve I added 182.5 million m^3 of water to the Cantareira system. The waterworks provided an additional reserve of 287.5 million m^3, which allowed for the supply of water to more than 6 million people during all 2014. Technical Reserve II added 105 million m^3 to the Cantareira system. As a result, the total volume of the Cantareira system is 1,269.5 million m^3, including Technical Reserve I and II (SABESP et al., April 30, 2015).

INSTITUTIONAL ACTIONS

To tackle this situation, authorities took a long-term approach that included (SABESP et al., April 30, 2015):

- An aggressive communications campaign focusing on water conservation aimed at the general population. For example: Ten films (television format) were produced throughout 2014/2015 and door-to-door distribution of flyers and promotional material on efficient use of water were conducted;
- Training and workshops with government entities, associations and NGOs on water savings;
- Negotiations with large private clients to incentivize them to reduce consumption and substitute the water provision from SABESP. In 2014, this initiative led 70% of customers to use alternative water supplies;
- Work with communities and social leaders to disseminate the gravity of the situation and to promote water savings;
- Encourage reused water consumption among large clients.

Savings obtained in March in Cantareira by action:
(in m^3/s)



TRANSFER OF WATER FROM OTHER PRODUCTION SYSTEMS

Given the dire situation in 2014, structural measures were also taken during the drought to transfer water from other production systems. Plans to construct additional water transfer infrastructure between reservoirs were accelerated. These transfers and use of existing interconnections allowed nearly three million people previously served by the Cantareira system to be serviced by other systems (SABESP et al., April 30, 2015).

The drought impacted severely millions of people in the São Paulo region. The pressure reduction measures taken to diminish leakages from the distribution system caused service disruptions for several days in some parts of the city (Nobre et al., 2016). Those most affected included the low-income segments of the population who could not afford to secure water from other sources, such as tanker trucks. To cope with the shortage, many residents began to collect rainwater, which was not stored safely in some cases. As a result, instances of dengue in São Paulo tripled between 2014 and 2015 (Otto et al., 2015). Prices of food rose by as much as 30% (Nobre et al., 2016). The drought also triggered episodes of social unrest throughout the city (Dobrovolski et al., 2015; Nobre et al., 2016). Further aggravating the situation, the drought also impacted hydropower production and pushed up energy prices, since 80% of the power in Brazil is generated by hydroelectric plants (Dobrovolski et al., 2015). SABESP experienced a 36.5% increase in energy costs (SABESP, 2015).

PROTECTING THE WATER SUPPLY: SÃO PAULO WATER FUND

In 2011, the Inter-American Development Bank, The Nature Conservancy, FEMSA Foundation, and the Global Environment Facility, came together in a public-private partnership to create and promote water funds, a financial and governance instrument aimed at conservation of nature-based water sources (or green infrastructure). The funds leverage public and private resources, investing financial returns in conservation projects. Today, resources are being invested in a series of green infrastructure projects that promote watershed conservation and complement investments in gray water infrastructure.

Created in 2013, the São Paulo Water Fund is making investments in green infrastructure that harness the power of nature to capture, infiltrate and regulate the water cycle. Among the activities of the Fund, there is a digital platform to map and register about 4,300 rural properties located in more than 80,000 hectares of the hydrographic basin that forms the Cantareira System, responsible for supplying 10 million people living in the metropolitan region of São Paulo.

These conservation actions are expected to generate environmental benefits, including river preservation, biodiversity conservation, and carbon absorption, which help combat climate change. To date, best practices have been conserved, restored and implemented in a total of 8,000 hectares, and have benefited 283 families directly in the upper part of the basin.

A FEW WORDS ON LA PAZ – EL ALTO, BOLIVIA

For the following section, the authors would like to acknowledge the support of EPSAS and MMAyA in providing the information relevant to the case.

The 2016 drought and deficit affected the lives of most urban and rural Bolivians, restricted clean water supply in seven of the main cities and revealed Bolivia's high vulnerability to such droughts. The events that took place on the highlands, valleys, and even plains were clear examples of this situation, where the number of afflicted municipalities outweighed any action or contingency plan for adverse climate change, leading the Ministry of Environment and Water (MMAyA) to supply 325 water storage tanks to help 53 counties in Potosí, Oruro, La Paz, and Cochabamba. The tanks' supply was depleted, while many municipalities and urban areas were still waiting for more suitable and timely responses.

Bolivia declared a national emergency due to water deficit on November 21, 2016 through Supreme Decree #2987, mandating the central government, autonomous departmental governments, and autonomous municipal governments to mobilize economic resources to guarantee proper water supply to the population. This was the first time that a drought hit the country's main cities so severely, triggering the implementation of emergency actions to mitigate and offer structural impact solutions to water scarcity in those communities.

The main factors behind this vulnerability included a absence of knowledge about risks and low monitoring and forecast capabilities, as well as weak inter-institutional coordination. The former is connected to limited hydrometeorological monitoring resources and the absence of specific instruments for droughts. One of the reasons for feeble coordination is insufficient institutional capacity to enforce coordination mechanisms following regulations —particularly at the local level. Another factor contributing to the country's vulnerability is a lack of major investments, especially in water supply infrastructure for urban centers, which tend to present a very dynamic growth rate.

Due to the severe impacts of the 2016 drought, metropolitan areas began to launch many projects and initiatives to improve resilience. These include infrastructure works and projects to strengthen knowledge on managing supply and demand, and monitoring droughts in different sectors, both at national and local levels.

The drought phenomenon isn't new to Bolivia, and water scarcity due to high climate variability has long been an issue in many parts of the country. Bolivia is currently working on improving hydric deficit management capabilities with several policies, programs and projects. The 2016 dry spell once again exposed the importance and urgency of such actions, leading to an accelerated implementation of scheduled programs and projects, and to the adoption of additional risk and risk management activities.

The meteorological drought that began in early 2016 due to lack of rains because of the El Niño event (one of the strongest on record, only comparable to those of 1982 and 1997-98, considered the worst El Niño of the 20th century) expanded during the year to a hydrological drought with low water levels in rivers, lakes and reservoirs, and to an agricultural drought affecting farming. The dry spell hit both rural and urban areas. The Department of Santa Cruz suffered crop losses in 480,000 hectares over two seasons, and Oruro reported the death of 206,000 heads of cattle. La Paz, El Alto, Cochabamba, and Sucre were severely struck, while Oruro, Potosí, and Tarija also reported water-related crises. A timeline of drought-linked events is presented below:

Starting in 04/2016	Rural municipalities suffer water deficits and request support from national authorities.
08/2016	The Agrometeorological Bulletin of the Ministry of Rural Development and Lands (MDRyT) reports: "We are experiencing meteorological and agronomical droughts in almost every area of agricultural production in our national territory."
08/2016	The national government passes 13 supreme decrees on August 2 aimed at helping agricultural production and tackling the drought crisis (DS 2849-2861.) The "Nuestro Pozo" National Groundwater Well Drilling Program (Programa Nacional de Perforación de Pozos de Agua Subterráneas "Nuestro Pozo") is created to ensure water availability for food security, and the Program "Cosechando Vida – Sembrando Luz" is modified to incorporate water harvesting for productive purposes.
10/2016	The departments of La Paz, Oruro, Potosí, Cochabamba, Chuquisaca, Santa Cruz, and Beni declare a state of emergency.
11/2016	Seven of the most important cities suffer water deficit.
11/2016	The President's Office establishes the Bureau of Water (Gabinete de Agua).
11/2016	Supreme Decree 2987 of November 21 says: "National Emergency situation due to the drought and water deficit suffered in different regions of the national territory, set off by climate events."
12/2016	The Ministry of Environment and Water introduces the National Emergency Plan for Droughts and Water Deficit (Plan Nacional de Emergencia por Sequía y Déficit Hídrico), MMAyA, 2016a.

TIMEFRAME OF EVENTS IN THE METROPOLITAN AREAS OF LA PAZ AND EL ALTO

During 2016, EPSAS, the water and sanitation operator in La Paz and El Alto, developed three contingency plans.

EPSAS Contingency Plans 2016

Name	Date	Purpose
Contingency Plan for El Niño 2015/2016	**October 2015**	Created by the EPSAS' Production Department in response to El Niño 2015/2016, and forecasts of its effects by the National Service of Meteorology and Hydrology (SENAMHI).
Contingency Plan for Dry Season 2016	Sent to the AAPS **April 29, 2016**	Developed by EPSAS as instructed by the Authority for Fiscal and Social Control of Drinking Water and Basic Sanitation (AAPS) to all regulated EPSAS, with special consideration to the drought risk forecasts caused by El Niño.
Contingency Plan for Drought 2016	Sent to the AAPS **October 7, 2016**	AAPS –by order of the MMAyA–, requests information from the set of regulated EPSAS on the general clean water and sewage systems, with a balance between supply and demand of the clean water systems.

SHORTAGE MANAGEMENT IN THE METROPOLITAN AREA OF LA PAZ

The shortage in 2016-17 in La Paz was even more traumatic because it was the first time that the city's residents faced such a situation. The aftermath of the droughts is proving dramatic, too: since 2015, six of the country's main cities –La Paz, El Alto, Cochabamba, Sucre, Oruro, and Potosí– have suffered critical water shortages. Official figures show this situation is affecting over 177,000 families, with 173 municipalities in distress. It's been estimated that the crisis has also affected more than 600,000 hectares of crops and almost 600,000 heads of cattle, and according to the Ministry of Rural Development and Lands, summer and winter season losses amount to US$125 million each.

IMPACT ON LA PAZ HOUSEHOLDS.

On average, each household has spent an estimated US$150 to mitigate the effects of clean water rationing. This cost includes everything from the purchase of pumps and tank cleaning, to the acquisition of containers and PVC storage tanks. This figure, multiplied by the number of homes, adds up to US$9.6 million just in the city of La Paz. The impact of this outlay on median income has been estimated at 16%. It's worth noting that these households' purchasing power had already been impacted negatively by higher food prices in city markets.

Affected households	Average expenditure on mitigating the impact on infrastructure and equipment replacement in households (US$)	Total cost (US$)
64,000	150	9,600,000

IMPACT ON HOUSE CONSTRUCTION AND OTHER INDUSTRIES

The restricted water supply in 94 La Paz sections also affected the construction industry. Building material costs rose 10% during the crisis and in many cases did not rebound after normal supply levels were restored. In the southern section of the city, several food establishments were forced to close due to lack of water. Below, additional information is provided regarding details of the contingency plans that were implemented to deal with the drought.

IMPLEMENTED MEASURES TO ADDRESS THE DROUGHT

The La Paz-El Alto Hampaturi dam project suffered a two-year delay with respect to the definition of the type of dam. First, the emergency had to be addressed, including the distribution of cisterns by the Army's Operation Center. The national government centralized all actions to deal with the severe rationing in the Pampahasi system, establishing a Special Operations Center controlled by the Army, which, due to the magnitude of the crisis, focused its efforts on: (i) establishing a specific center for water shortage claims capable of handling all cases; (ii) programing, loading, supplying and distributing drinking water via more than 80 cisterns; and (iii) installing more than 150 tanks of 10m3 capacity in different sectors of affected areas to be used as public pools.

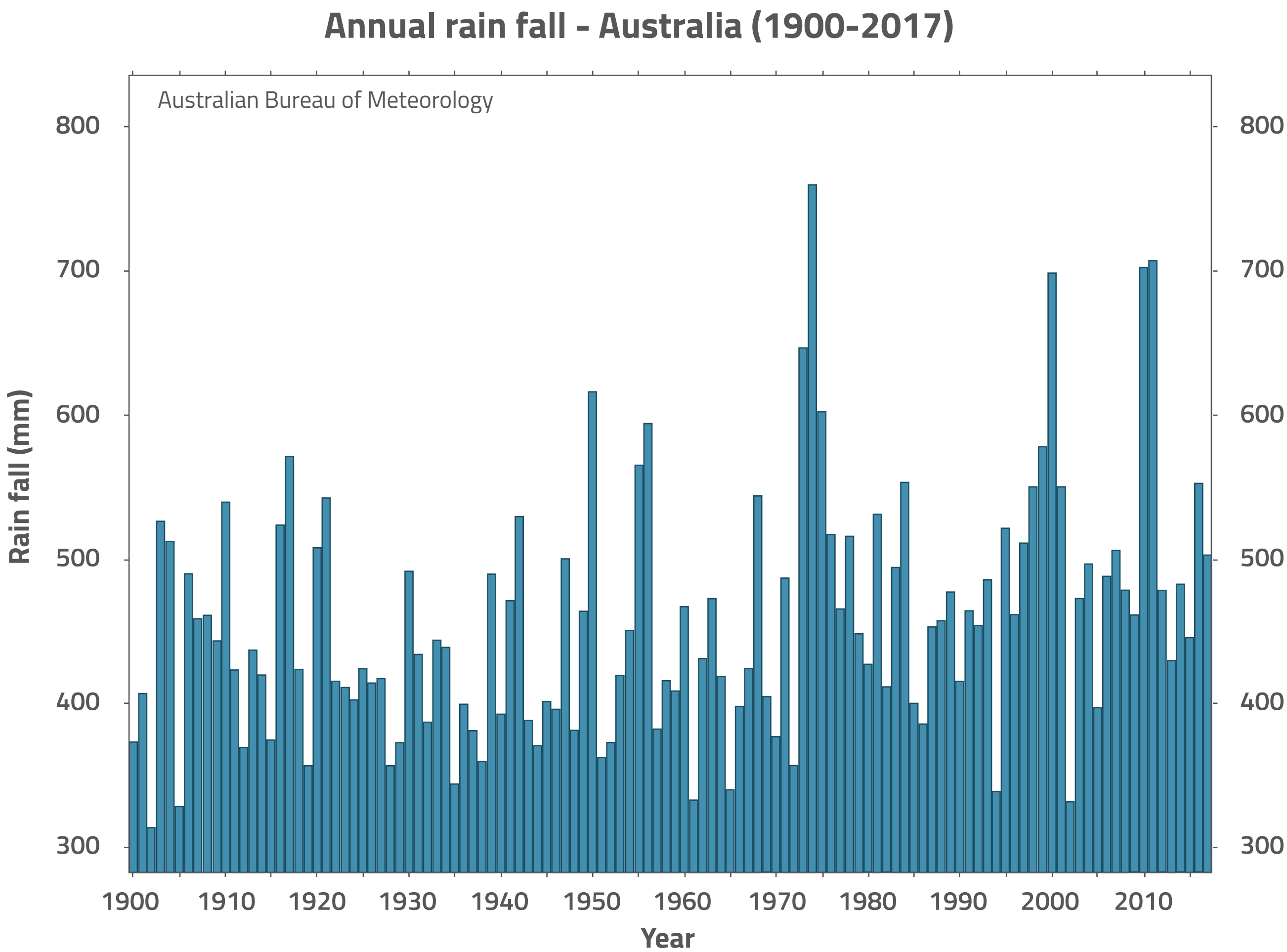
Crisis management action improvement included: (i) supply and demand balance (achieved); (ii) implementing a drought response plan; (iii) reliance on early warnings; (iv) improvement of distribution efficiency.

AUSTRALIA

Bathed by the sun of their Mediterranean climates, Australia, California and South Africa's Western Cape are drought-prone regions that are especially vulnerable to climate change because they depend on captured winter rainfall or snowmelt. The three most recent severe drought experiences give valuable insights to policymakers with respect to water security and water resource management.

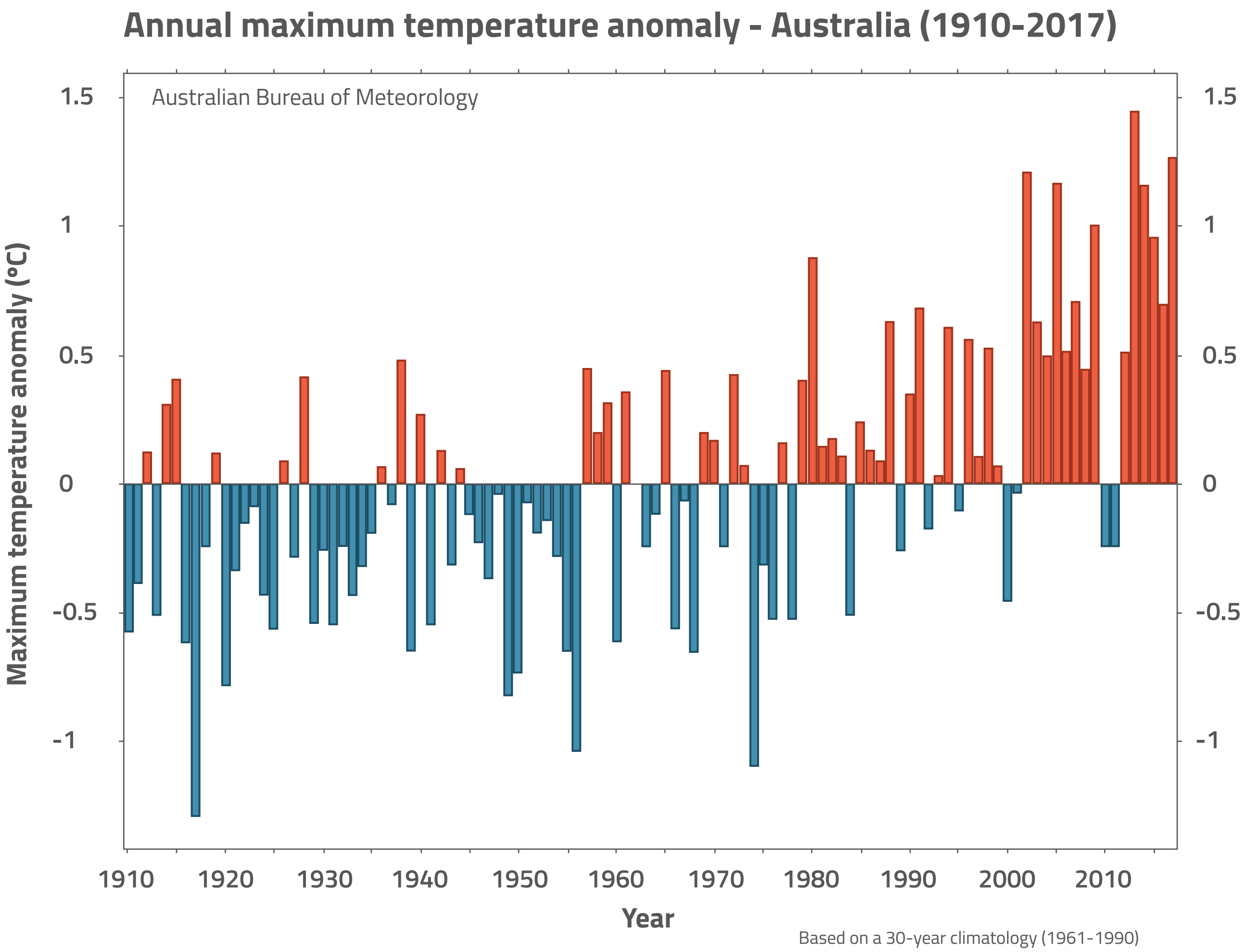
CONTEXT

Australia’s Millennium Drought, which lasted more than a decade in some areas, was the worst dry spell in the country’s recorded history. It was the longest uninterrupted series of years with below median rainfall in southeast Australia since at least 1900s (Institute for Sustainable Futures, 2017).



Source: Australian government : Bureau of Meteorology

This drought lasted from 1997 to 2012 and was characterized by severely hit river ecosystems and irrigated and dryland agriculture in Victoria and the Murray-Darling Basin, Australia's largest river system. The effects of the drought on water availability were compounded by historically high temperatures over the same period.



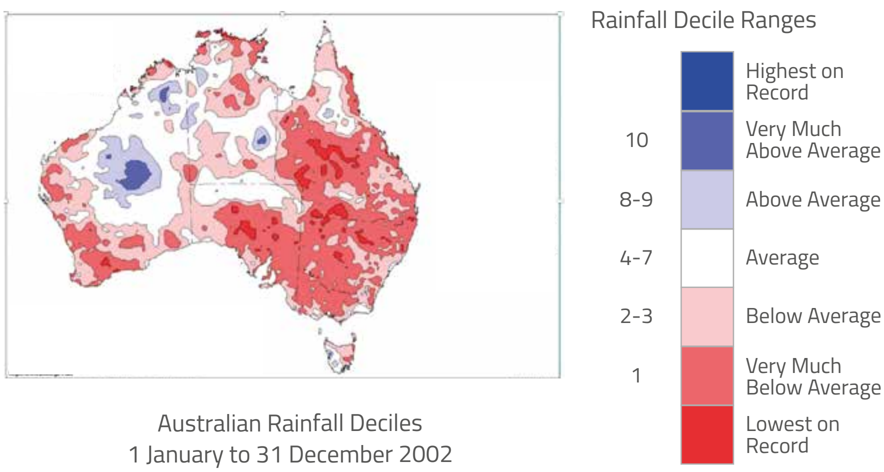
Source: Australian Government: Bureau of Meteorology

The drought placed extreme pressure on agricultural production and urban water supply in much of southern Australia. Australia's cotton production dropped 66% compared to five years earlier. The industry's water use fell by 37% between 2000/01 and 2004/05, due mainly to the drought. The main areas affected were in New South Wales (Cotton Australia, 2007).

In June 2008, it became known that an expert panel had warned of long-term, and perhaps irreversible, severe ecological damage for the whole Murray-Darling Basin. The very low flow to the Lower River Murray in South Australia resulted in the lowest water levels in over 90 years of records. The lowest water levels during the extreme low flow period were reached in April 2009 and represented a 64% and 73% reduction in the volume of Lakes Alexandrina and Albert, respectively. Exposure and oxidation of acid sulfate soils due to falling water levels from 2007-2009 in the Lower River Murray and Lower lakes also resulted in acidification of soils, lake and groundwater. The drought's environmental legacy persists in parts of the system. For example, as of 2014, Lake Albert's salinity was still elevated four years after the drought and acidity persists in soils and groundwater (Mosley et al., 2014).

The drought changed the way Australia managed its water resources. Most Australian mainland capital cities faced a major water crisis with less than 50% of water storages remaining. The drought had a material impact on Australia's National Electricity Market. It reduced output from major hydro-electric generators Snowy Hydro and Hydro Tasmania, and constrained output from some coal-fired generators that use freshwater for cooling. The Australian Energy regulator found that these effects led to noticeably higher prices (Australian Energy Regulator, 2008; Jung et al., 2010; Leblanc et al., 2012).

Australian Government
Bureau of Meteorology



Australian Rainfall Deciles
1 January to 31 December 2002
Distribution Based on Gridded Data
Product of the National Climate Centre

http://www.bom.gov.au

Issued: 01/01/2010

Due to declining dam levels, Australia undertook massive investments in major new water supplies, including the construction of six major seawater desalination plants to provide water to Australia's major cities. It also spearheaded changes in the management of water in the Murray-Darling Basin (USD7.2 billion). Then-Prime Minister John Howard responded to extreme weather conditions to announce a major water policy reform agenda in January 2007, known as the National Plan for Water Security. This led to the passage of the Water Act (2007) by the Commonwealth Parliament, the formation of the Murray-Darling Basin Authority in 2008 and the publication of the Murray-Darling Basin Plan under the Gillard government in 2012 (Parliament of Australia, 2007). In addition, Australia made significant investments in water efficiency programs (Institute for Sustainable Futures, 2007).

The gradual realization of the severity of the drought and Australia's vulnerability triggered a series of responses that included cutting-edge innovations, as well as both very good and poor examples of water planning and management in Australia's four largest cities: Sydney, Melbourne, Brisbane (and the surrounding southeast Queensland region), and Perth. The concern about climate change increased political will for action, as well as the funding available for drought response measures and the potential for shifts in policy and water use. These concerns highlighted the need to diversify water sources by adopting measures that included water efficiency, source substitution, major reuse, and non-rain-dependent supplies, such as desalination (Turner et al., 2016).

MEASURES IMPLEMENTED

In Australia, urban water efficiency was successful, saving more water at lower cost and greater speed than supply options. It's a matter of both supply and demand. The Millennium Drought offers important insights regarding both supply-side and demand-side options. For instance, on the demand-side, the WaterFix program reached nearly half a million homes in Sydney, about a third of homes in the Greater Sydney area (Institute for Sustainable Futures, 2007). 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 US$16 (AUD 22) for the plumber to visit the home, plus an additional amount for any services rendered, and could repay the water utility for these services over a four-month period (Institute for Sustainable Futures, 2007).

Some **demand-side programs** implemented in Australia included:

- Toilet replacement program, which consisted of replacing two single flush toilets with new efficient dual flush toilets with a rebate from state government;
- Washing machine rebate program; and
- Outdoor water use restrictions in residential and some non-residential sectors.

(Institute for Sustainable Futures, 2007).

These programs were implemented while infrastructure projects were being planned, constructed, and resulted in savings equal to 63 liters per person, per day in Sydney in 2008/09 (Institute for Sustainable Futures, 2007). The toilet replacement program was a relatively cost-effective initiative, which achieved high participation rates. Most major programs partnered with specific plumbing services and major toilet suppliers to reduce costs and provide a consistent product and service. The washing machine rebate program was a popular and cost-effective rebate program which overall helped transform the stock of washing machines from inefficient models (often top-loaders) to front-loading efficient machines. These typically used half the water per wash. This was a very successful program, which is still being implemented today (Institute for Sustainable Futures, 2007).

Powerful demand-side programs encouraged and supported water savings among water users and stakeholders – households, businesses, industries and governments. This maximized the potential for water savings and could achieve economies of scale, particularly for household programs that target multiple uses and residents. Involvement of all sectors of the community fostered a sense of fairness and collaboration in saving water, as well as acceptance and support for overall drought response strategies, including restrictions and targets (Institute for Sustainable Futures, 2007). For instance, the Target 140 campaign was introduced to encourage individuals to reduce household water demand to less than 37 gpcd (140 lcd) from pre-drought levels of 79 gpcd (300 lcd). The Target 140 campaign ran for eight months, cost USD3 million and reached 2.3 million people, at a cost of less than USD1.4 per person (Institute for Sustainable Futures, 2007).

The figure below indicates the list of demand-side measures that were implemented to tackle the drought. It is useful 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 water and energy (Institute for Sustainable Futures, 2007).

Demand-side Measures

Measures	Strengths	Challenges
Targeting outdoor water in residential and non-residential sectors	Restrictions implemented by water utilities in collaboration with state governments were highly effective at reducing water demand	Private green areas, trees, and gardens were affected, causing loss of amenity and recreational value
DIY Water Savings Kits Free regulators and aerators for showers and taps in public places	Low-cost measures to implement were very effective in achieving water savings and high participation rates and measured savings	Risks that many of the kits were not installed
Shower Swaps Exchange of inefficient showerheads for efficient devices at no charge	Cost-effectiviness attracted high participation and savings	Consumer adoption depends on quality of shower experience
Toilet Replacement Program Replacement of up to 2 single flush toilets with a new efficient toilet + rebates by a qualified pumber	Cost-effective initiative. High participation rates and measured savings	Reduction of savings per household relative to opportunity
Washing Machine Rebate Program Top 10% residential water users using 3.7 gpcd (140 lcd)	Popular and cost-effective rebate program	More efficient machines were available at a lower cost (free-riders limited cost-effectiveness)
Rainwater Tank Rebates Top 10% residential water users using 3.7 gpcd (140 lcd)	Rainwater tanks were effective in capturing water	Overestimation of water savingsto be achieved caused some rebate programs to have a non-effective cost

Measures	Strengths	Challenges
Targeting high residential users Top 10% residential water users using 3.7 gpcd (140 lcd)	Highly effective program: reduction of per capita water usage	Further savings could have been achieved with more direct approaches (eg. social media)
Target 140/150 Innovative multi-media & multi strategy campaign to foster water reduction in household water use	Successful due to strong focus on research about the attitudes of target audience	Difficult to measure savings due to timing and seasonal effects
Waterless works Subsidies provided to swap water with waterless equivalent	Increased collaboration of community groups	---
Pressure and leakage management Increasing investments in water mains inspection for leakage	Low cost, "no regrets" option, strong community relations and quick response times increased community interest and reporting of leakages	Limited experience within some utilities increased the time to develop necessary expertise

(Reference: Institute for Sustainable Futures, 2007).

Supply-side measures are considered 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 prevent costly post-drought stranded assets.

- > Clear, credible communication about the drought situation and response is crucial to public participation and support to disseminate information about water savings, storage levels, requirements and expectations about drought;
- > Good data and robust monitoring and evaluation are critical, down to the household level to implement well targeted water saving measures; and
- > Innovative water pricing mechanisms are required to balance water savings, revenue and equity goals.

As mentioned above on the demand-side, the figure below indicates the list of supply-side measures that were implemented to tackle the drought.

Supply-side Measures

Groundwater extraction		
Infrastructure for long-term emergency replenishment of water supplies	Illustration of "readiness approach" to implementing drought responses	Marginal cost of water is relatively high if only used during drought (as the cost to store water for the sole purpose of a future drought is high)
New inter-catchment transfers		
Construction of new pipelines and channels to transfer water from other catchments	Useful for increasing yield and reducing risk in some areas	Infrastructure development was widely criticized

Desalination

Construction of seawater desalination plants for water supply	Independent source of supply that increases reliability of the system helps diversify supply	More cost-effective water efficiency options were applied

Major reuse

Large scale, high quality recycled water treated for residential estates	Helped slow the depletion of potable water supplies	Significant government funding provided during the drought led to many non-financially viable schemes

Note: How do we know that the marginal cost is high? It is much more expensive to store water for "just in case" scenarios than to find additional supplies when you need them. This is why we use the term "marginal cost of water." Stored water is not used until there is a drought. It cannot be sold.

(Reference: Institute for Sustainable Futures, 2007).

RECOMMENDATIONS FROM THE MILLENNIUM DROUGHT

Investment. The Millennium Drought stimulated investments related to water resource management, including applied research or water efficiency programs that previously were not public policy agenda priorities. These new areas of interest, coupled with restrictions on outdoor water use, resulted in a significant decrease in water demand. For instance, in Southeast 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 help delay or eliminate the need for expensive, new water and wastewater infrastructure to accommodate future population and economic growth (Institute for Sustainable Futures, 2007).

Some Australian utilities were 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) and encouraged investment in supply-side options rather than demand-side options, irrespective of the cost-effectiveness of those options (Institute for Sustainable Futures, 2007).

Large-scale water recycling has been implemented in almost every major Australian city as a result of the drought. The largest is the Western Corridor Recycled Water Scheme, which was completed in 2008 at a cost of USD1.9 billion. The plant was shut down in 2013 to reduce long-term costs, with start-up arrangements in place should the water be needed (Institute for Sustainable Futures, 2007).

Planning. New policy measures were also developed. For the first time, governments contemplated "readiness" contingency plans. One example was Sydney's "ready to construct" 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 (Institute for Sustainable Futures, 2007).

In addition, the Millennium Drought saw, for the first time, the application of 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 (Institute for Sustainable Futures, 2007).

Hence, during a drought, it is essential to consider an integrated resource planning framework that ensures that all options (supply and demand) are assessed and compares them on a level playing field, and that the framework includes risk and the full range of costs and benefits (Institute for Sustainable Futures, 2007).

Partnership. Strong partnerships, knowledge sharing and coordination among diverse entities, including states, agencies, utilities, researchers and industries, contributed to the success during and in the aftermath of the Millennium Drought. For example, across Australia, "green plumber" programs were supported to encourage tradespeople to become involved in the task of improving water efficiency. In the state of New South Wales, for example, the "Water CEOs' group", comprised of the heads of all water-related agencies and water utility CEOs, was convened and tasked with managing the drought response. Sharing information and experiences across the industry –among utilities in each state and among state government agencies– also helped 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 demand and potential savings (Institute for Sustainable Futures, 2007).

Communication. Communication and public engagement savings programs related to the water scarcity situation were essential to the success of all water saving initiatives because of community support and action. 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 (Institute for Sustainable Futures, 2007).

It is important to note that 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. Engagement, in turn, engenders citizen support. Cost-effective water saving measures that had never previously been implemented at scale were rolled out across states and cities, such as rebates for water efficient washing machines in Western Australia (Institute for Sustainable Futures, 2007).

CALIFORNIA

For the following section, the authors would like to acknowledge the support of the San Francisco Water Utility in providing the information relevant to the case.

CALIFORNIA'S URBAN WATER SECTOR

The data in this section were drawn from a June 2017 document from the Public Policy Institute of California, entitled "Building Drought Resilience in California's Cities and Suburbs."

The State of California is the most populous state in the United States, with 38 million people. Water systems are highly decentralized. More than 400 retail utilities are classified by the state as urban water suppliers. Each urban utility serves at least 3,000 homes and businesses, and many more supply water to about 93% of the state's population. The rest of the population is served by roughly 2,500 small, mainly rural community water systems, serving between 15 and 3,000 customers, or by very small water systems or domestic wells.

Most urban retailers (83%) are local public agencies. About half are city or county water departments, governed by city councils or county supervisors. A third are special districts governed by publicly elected boards. The remaining 17% are run by private investor-owned utilities. About half of all urban retailers receive a portion of their water supplies from wholesale utilities. The largest of these—the Metropolitan Water District of Southern California--serves roughly half the state's population across six counties.

Key state agencies involved in urban water system oversight and policy include the State Water Board (water rights administration, water quality enforcement), the Department of Water Resources (DWR--water resources planning, operating the State Water Project), and the California Public Utilities Commission (CPUC--regulation of water rates for private utilities).

IMPACTS OF THE DROUGHT

The data in this section were drawn from a June 2017 document from the Public Policy Institute of California, entitled "Building Drought Resilience in California's Cities and Suburbs."

The 1976-1977 drought was a wake-up call in California and the first major drought experienced in urban areas of the state. The drought changed the ways in which policy makers and urban water utility managers thought about water. It also exposed the inadequacy of past water supply planning and highlighted the need for more water supply diversification. It also demonstrated that water transfers and exchanges can help mitigate the worst effects of drought and highlighted the need to reform water rights law to facilitate those exchanges.

The 1987-1992 drought was the longest one to hit California since the 1930s. It resulted in water transfers, conservation and recycling becoming fundamental elements of urban planning and management in California. The 2007-2009 drought highlights included conservation targets and the imposition of new export restrictions in the Sacramento-San Joaquin Delta (the hub for moving Central Valley Project and State Water project water from the state's high mountain watersheds to distant farms and cities.

The 2014-2016 drought had wide-ranging impacts and led to a variety of responses at the local level, including reduced availability of one or more supply sources (71%), water quality problems (40%), infrastructure management difficulties or damage (21%), water theft (18%), and several challenges in managing watersheds and services, such as wastewater.

The impact on agriculture was dramatic, with more than US$1.8 billion in direct losses. In addition, 21,000 seasonal and part-time farming jobs were lost, and 540,000 acres, or 5% of the state's total agricultural land, went out of production. The impact on drinking water was also significant, with 2,611 wells reported at critical level or totally dry. CalFire responded to 6,335 wildfires across the state during 2015 compared to a five-year average of 4,588 wildfires. Fires burned 307,598 acres in 2015 compared to a five-year average of 109,989 acres. Fish and wildlife also were severely impacted.

FINANCIAL AND ECONOMIC IMPACTS

The data in this section were drawn from a June 2017 document from the Public Policy Institute of California, entitled "Building Drought Resilience in California's Cities and Suburbs."

Both the drought and the actions implemented to address it had significant repercussions for water suppliers' finances, as well as more limited effects on local economies in their service areas. More than 60% of suppliers reported the drought somewhat or greatly reduced their revenues and their net financial position. Operational costs associated with drought management activities, such as increased customer outreach, enforcement of water use restrictions, and conservation program deployment also increased. Statewide, total reductions in urban water supplier net revenues in 2015 likely approached USD1 billion, with more than half of this figure related to crisis abating measures.

As seen earlier, 75% of all water suppliers adjusted their water rates in response to the drought, and many also instituted financial penalties (79%) or drought surcharges. Concerns about the drought's severity prompted the state to intervene in new ways and adopt a more hands-on approach to short-term demand management. In 2015, for example, the state took the unprecedented step of ordering an across-the-board mandate for urban water conservation. Although California's residents overwhelmingly responded to the mandate, the policy generated significant discord between the state and local water suppliers—entities that need to work well together to protect the state's residents and economy from the worst effects of drought.

During the early stages of the drought, California Governor Jerry Brown proclaimed a state of emergency, calling on Californians to voluntarily reduce their water usage by 20% and directing urban water suppliers to immediately implement their water shortage contingency plans. 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. This marked the first time that state authorities mandated a statewide reduction in urban water use.

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 paying from USD0.50 to USD5.00 per square foot of lawn replaced with low water-use landscapes. 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.

Actions in the following five areas can serve as recommendations to improve drought resilience going forward:

> **Coordinating water shortage contingency planning and implementation:** The stress-test the state adopted toward the end of the drought—which allowed local utilities to drop mandated conservation if they could demonstrate drought-resilient supplies—proved to be a good model in this context.

> **Fostering water system flexibility and integration:** Priorities include continued local and state investment in cooperative regional approaches to water supply management and greater attention to the regulatory context in which planning, and investment decisions are made.

> **Improving water suppliers' fiscal resilience:** Utilities can improve their ability to weather future droughts by being more proactive on drought pricing and communication with their customers.

> **Addressing shortages in vulnerable communities and ecosystems:** Simply saving water in cities is not enough to provide meaningful assistance to at-risk rural communities and ecosystems. The state needs to take the lead in improving drought preparation and response for these vulnerable sectors.

- **Balancing long-term water use efficiency and drought resilience:** As water managers look to make long-term gains in conservation, they need to recognize that reducing water used by urban landscapes will make it harder to cut water use quickly during future droughts. Prolonged droughts can disrupt service, harm customers and weaken utility finances.

The mandate's effect on urban water use was significant and immediate. Water savings began in April 2015—immediately following Governor Brown's executive order. The aggregate savings rate for June 2015 to February 2016 was 24%, just shy of the 25% the governor ordered.

RESPONSE TO THE DROUGHT IN CALIFORNIA

Improvement of water efficiency standards

The drought intensified the adoption of irrigation technologies for crops that used them before and led to their adoption for crops normally grown with traditional irrigation methods. California has been a leader in promoting water use efficiency standards for indoor plumbing fixtures and appliances since the 1976–77 drought (Public Policy Institute of California, June 2017).

Today, California has the most stringent water efficiency regulations in the nation for plumbing fixtures. New toilets and urinals cannot use more than 1.28 and 0.125 gpf, respectively. Showerheads were limited to 2.0 gallons per minute (gpm) and were further reduced to a limit of 1.8 gpm in 2018. Bathroom, kitchen, and public lavatory faucets cannot use more than 1.2, 1.8, and 0.5 gpm, respectively. The state has also aggressively pushed for more stringent water efficiency standards for clothes washers. A typical residential clothes washer made in the 1990s used about 12 gallons per cubic foot of capacity. In 2015, the allowable use for top- and front-loading residential washers was reduced to 8.4 and 4.7 gallons, respectively. These efficiency requirements have resulted in new and remodeled homes having a much smaller "water footprint" than older homes and, along with utility-sponsored retrofit programs, have been key to driving down the state's indoor residential water use (Public Policy Institute of California, 2017).

The critical situation in California has led to new water policies about recycled water. According to the State Water Resources Control Board (Division of Financial Assistance, Municipal Wastewater Recycling Survey), Recycled water or treated municipal wastewater currently satisfies 7% of the state's annual water demand. Recycled water use increased significantly between 1970 and 2009, from 175,000 acre-feet per year to 669,000 acre-feet per year. Recycled water use in California covers the following: recreational impoundment (4%); natural systems (5%); agriculture irrigation (37%); landscape irrigation (18%); groundwater recharge (10%); golf course irrigation (6%); seawater intrusion barrier (8%); and geothermal energy production (2%).

More than 70% of urban water suppliers imposed mandatory quantity and type-of-use restrictions (such as limits on landscape watering). Nearly all urban water suppliers implemented public education programs and provided water conservation kits to customers—including items like free low-flow showerheads, toilet dams, and toilet leak detectors—and about one-third offered customer water audits and incentives for ultra-low-flow toilets (Dixon et al., 1996).

Long-term demand management programs have contributed significantly to the long-term decline in urban per capita water use that began in the 1990s. In 2010, average urban daily water use was 178 gallons per capita, down from 220 in 2000. Most of the long-term gains in water efficiency have been indoors, aided by the adoption of low-flow plumbing fixtures and appliances (Public Policy Institute of California, 2017).

Self-Certification: In May 2016, following a near-normal winter and improved water storage conditions, the State Water Board replaced the conservation mandate with a self-certification process. This allowed suppliers to opt out of state-mandated conservation targets, provided they could demonstrate they had supplies adequate to carry them through at least three more years of drought without mandatory rationing. The new standards were in effect from June 2016 until the drought emergency was lifted in April 2017. Water suppliers could opt out of self-certification by continuing to be subject to the state mandate. Only 8% chose this alternative (Public Policy Institute of California, 2017).

The State Water Board took a series of actions to address the increasing severity of water supply conditions across the state.

The following figure presents a timeline of the measures (Public Policy Institute of California, San Francisco Water Power Sewer Drought Report: 2014-2016).

TIMELINE OF THE DROUGHT

2014

State-promoted conservation

Urban water use reporting

State-wide savings: 10%

January, 2014
Governor declares drought emergency and requests 20% voluntary state-wide urban conservation

January 31, 2014
Voluntary reduction in water consumption by at least 10% state-wide

August 12, 2014
Mandatory 10% reduction on outdoor irrigation consistent with the State Water Board´s emergency regulations

Widespread use of demand management measures and water shortage contingency plans

2015

State-mandated conservation

April 2015
Governor mandates a statewide water use reduction of 25% compared to a 2013 baseline

July 1, 2015,
Reduction in retail potable water outdoor irrigation by 25%

Increased use of "sticks" (penalties, surcharges, use restrictions)

June 2015
Water Board adopts mandadory conservation regulations

2016

Extension of Water Board mandatory conservation

February 2016
Water Board extends mandatory conservation regulations

Improving the efficiency of irrigation systems

June 2016
State Water Board authorizes agencies to self-certify drought water supply

Self-certification of drought resilient supplies widespread

State-wide savings: 20%

2017

Self-Certification

June 2017
Water Board agencies authorize self certification of drought water supplies

April 2017
Governor declares end of drought emergency and announces long-term conservation strategy

Statewide savings: 20% (regional range 17-26%)

Through its conservation program, California has been able to replace 80,000 toilets and 30,000 clothes washers. Other measures include the blending of groundwater with surface water supplies, new groundwater wells in San Francisco, balancing management of groundwater and surface water, using non-potable water to clean select streets, and plans to treat subsurface nuisance groundwater for additional street cleaning needs (Public Policy Institute of California, San Francisco Water Power Sewer Drought Report: 2014-2016).

Conservation measures: Plans for the 2015-2040 period include urinal rebates, urinal direct install, toilet rebates, single family toilet direct install, multi-family and non-residential toilet direct install, clothes washer rebates, equipment retrofits, landscape surveys and grants, residential grey water and rain barrel incentives, education and outreach, audits and reports, and device distribution (Public Policy Institute of California, San Francisco Water Power Sewer Drought Report: 2014-2016).

Climate change aspects: California's long-standing concerns on water resources have been growing given climate change impacts. These impacts affect the availability, quality and distribution of water via –among others– warmer temperatures, modified precipitation patterns and runoff, rising sea levels, loss of natural snowpack storage, and more frequent extreme climatic events (California Department of Water Resources, 2008). Although the state endured several multi-year droughts since 1900 (State of California et al., 2014), evidence indicates that climate change has significantly increased the magnitude of these events (Williams, 2015) leading to considerable economic and social impacts. For instance, the 2013/14 drought –the driest 12-month period on record– registered less than 34% of the average precipitation (Swain et al., 2014), and the 2016 drought resulted in losses of USD600 million and 4,700 jobs statewide (Medellín-Azuara et al., 2016). Water planners hence face the challenge of how to consider climate change impacts in the decision-making process (California Department of Water Resources, 2009), and adaptation strategies are imperative for California's water community to improve resiliency, reduce risks and increase sustainability (California Department of Water Resources, 2008).

California is a frontrunner on climate action, with an extensive history of enacting legislation, regulations and executive orders to reduce greenhouse gas emissions while addressing climate change impacts. The 2009 California Climate Change Adaptation Strategy (CAS) updated in 2018 –the first step to reduce the state's vulnerability– highlighted the need to change water management and uses given climate change impacts that will likely increase the competition for limited water supplies among urban and agricultural uses (California Natural Resources Agency, 2009).

COMMUNICATION AND EDUCATION

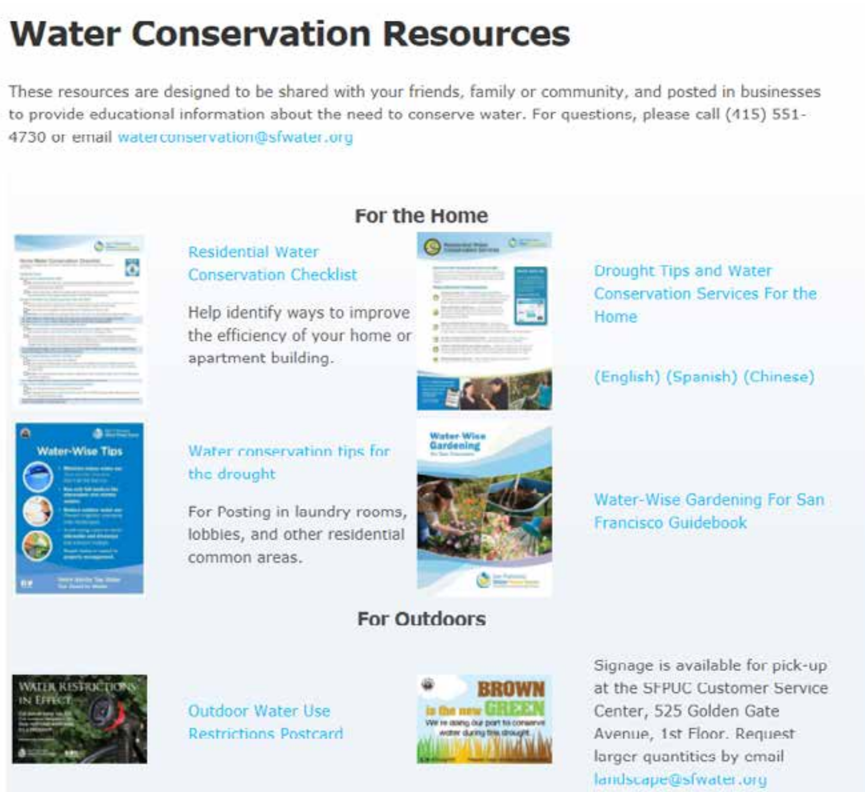
In California, outreach and education programs were key for implementing water savings and related measures. For instance, in June 2014, the SFPUC launched a multilingual "Water Conservation is Smart and Sexy" citywide public education campaign.

Other water conservation resources. Screenshot website

The target of the campaign was the general public, and the objective was to create awareness to introduce everyday tips and information on water savings and drought.

A series of messages designed for a combination of platforms and formats, such as digital, print and media (both social media and traditional media) was geared toward promoting positive behavior in terms of water use practices and water-efficient household infrastructure (new, fixture and upgrades).

San Francisco Public Utility Commission's (SFPUC) water conservation website hosted content about the campaign and more information about the services offered.



Water Conservation Resources

These resources are designed to be shared with your friends, family or community, and posted in businesses to provide educational information about the need to conserve water. For questions, please call (415) 551-4730 or email waterconservation@sfwater.org

For the Home

Residential Water Conservation Checklist

Help identify ways to improve the efficiency of your home or apartment building.

Drought Tips and Water Conservation Services For the Home

(English) (Spanish) (Chinese)

Water conservation tips for the drought

For Posting in laundry rooms, lobbies, and other residential common areas.

Water-Wise Gardening For San Francisco Guidebook

For Outdoors

Outdoor Water Use Restrictions Postcard

Signage is available for pick-up at the SFPUC Customer Service Center, 525 Golden Gate Avenue, 1st Floor. Request larger quantities by email landscape@sfwater.org

The SFPUC also implemented a public education program about wasteful outdoor water use activities restricted by the state, such as outdoor hardscapes washing; watering landscapes; and operating a hose without the use of an automatic shut-off spray nozzle. Actions included targeted messaging to top water-using residential accounts, individuals demonstrating outdoor water waste, and commercial properties performing maintenance of outdoor hardscapes (San Francisco Power Water Sewer Drought Report: 2014-2016, November 2016).

The SFPUC also established a public water waste reporting and tracking system through the City of San Francisco's centralized 3-1-1 online and telephone response center. Over a 10-year period, the San Francisco Public Utility Commission was able to see a reduction in consumption from 223 liters per person and per day (lpd) on average, to 185 lpd among residential customers (San Francisco Power Water Sewer Drought Report: 2014-2016, November 2016).

Will water savings persist? Data from June through December 2016 showed a slight dip in conservation, but savings remained high with cumulative urban water savings of approximately 20% relative to 2013. For water suppliers, the bigger question is how much of the reductions in water use achieved during the drought will be temporary versus permanent. About 60% of suppliers indicated that they were likely to reassess their water demand forecasts pursuant to the drought. Yet, it is too soon to know how urban demand will evolve in the long run. To the extent that households and businesses made efficiency improvements in their indoor plumbing appliances, these adjustments to their water use will be long-lasting. All this indicates that while some rebound in water use is inevitable, per capita use may never fully return to its pre-drought levels (Public Policy Institute of California, 2017).

A FEW WORDS ON CAPETOWN, SOUTH AFRICA

Context. Cape Town, a city of four million people that welcomes two million tourists every year, has been going through a very severe drought since 2015. The drought has worsened significantly over time, with total rainfall about 50% to 75% of the long-term average. It is believed that socio-economic factors have played a role in making the water crisis worse. Cape Town's population grew 2.6% between 2001 and 2011 due to rural-urban migration to Cape Town (Wolski, 2018).

Economic cost. The Western Cape economy represents approximately 13% of the South African national economy. The wine industry, one of the biggest exporters, has been hit severely by the drought, and is now down by 20%. Fruit and vegetable production (onions, potatoes and tomatoes) has dropped by 15%.

Political tension. Tackling the crisis has proven to be difficult due to bureaucratic inertia and tensions between the national and provincial governments, led by opposite political parties (Wolski, 2018).

Water supply. Cape Town's water supply is based almost exclusively on surface water reservoirs. There are 14 reservoirs, with around half (the "big six") storing 99% of the water (Wolski, 2018). The capacity of these reservoirs decreased dramatically over time: in 2014, reservoirs were at 100% capacity; in 2015, levels were at 75%; in 2016, they were at 62%; and in 2017, capacity reached only 33%.

Measures. In September 2017, the City of Cape Town introduced stringent restrictions on water use, imposing a limit of 87 liters (or 23 gallons) per person, per day. While the restrictions were voluntary because there was no way to enforce them at scale, they were quite successful; water use dropped by 25% compared to previous years. At the end of 2017, however, there was a limited response to water use restrictions since only 33% of consumers were below the targeted 87 liters per person per day.

In addition, local officials presented an ambitious plan to supply the city with additional sources of water (mostly from desalination and groundwater), which was equivalent to expanding the system by 50% in less than a year (Wolski, 2018). However, it became soon apparent that implementing those measures would be almost impossible in so little time. The reasons for that were:

- two potential groundwater aquifers existed, but they were not developed for exploitation and very rapid protecting was needed;
- with respect to alternative sources, water reuse and desalination were possible technologies to use but their implementation at scale would be a major engineering and financial challenge due to the time constraint (Wolski, 2018).

In February 2018, water use restrictions were further tightened to 50 liters (13 gallons) per person, per day (which means toilets can only be flushed once and showers have to be limited to 10 liters), with fines for households that used more than 6,000 liters per month. Seven programs, including boreholes and desalination schemes, are underway to increase water production.

The city is now implementing level six water restrictions, which are the most drastic measures it has implemented so far (City of Cape Town, 2018). As of January 1, 2018, these include:

- Prohibitions against the use of the city's drinking water for gardening, filling swimming pools or washing cars;
- Farmers must reduce their consumption by 60%;
- Institutions and businesses must cut their consumption almost in half;
- Hotels have removed plugs from rooms to prevent guests from taking baths.

Cape Town is at risk of becoming the first major city in the world to run out of water. The day on which the taps would run dry is called Day Zero and it will happen if water levels in dams drop below 14%. While the exact date of Day Zero is difficult to predict because the 14% dam level will depend upon rainfall and water availability, it is expected that Cape Town's taps will run dry in 2019. Most scientific projections point to a hotter and drier climate for Cape Town, forcing a sustained decrease in demand and the use of alternative sources of supply.

LESSONS LEARNED FOR FUTURE DROUGHTS

Every major drought provides opportunities to draw lessons for better managing the next one. This is particularly relevant in Latin America and the Caribbean, where the effects of climate change through droughts and floods are becoming more frequent and intense, have affected rural areas and have also been particularly devastating to cities' water supplies.

Water and sanitation infrastructure. When considering the cost of large-scale supply infrastructure projects, these need to be analyzed together with both the immediate and long-term costs of the drought, particularly when factoring in overall diminishing economic activity. Depending on the context, large infrastructure works can be more expensive and have longer lead times for implementation and results. Hence, while an individual demand-side program may save less water in total than what large-scale infrastructure could supply, this does not by itself justify prioritizing all supply options (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

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. Due to declining dam levels, Australia made massive investments in major new water supplies, including US$7.2 billion in six seawater desalination plants and several recycled water plants. Water customers are still repaying substantial capital costs through significant water tariff increases 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 into the networks. These examples highlight the risks associated with building large, expensive new supplies to meet needs during drought periods (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

In addition, large-scale wastewater reuse initiatives were implemented, such as the Western Corridor Recycled Water Scheme, which have experienced significant reduced demand (Alliancefor Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016). Many of the major cities in Australia now have a higher energy intensity for delivering water than they did before the drought since desalination plants and associated interconnecting pipe grids require additional pumping (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

Moreover, water demand management has been highly successful in reducing demand over the long-term and has contributed to short and long-term savings. However, the investment research, modeling implementation teams and the programs themselves have been significantly curtailed since the drought ended. It is a major concern for Australian utilities that the potential savings are being eroded due to a lack of ongoing maintenance of those programs, the lack of communication to customers about the need to keep water usage down and the loss of industry knowledge (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

A least-cost planning approach could help avoid costly mistakes. This requires considering the full range of supply and demand measures and selecting the lowest unit cost measures first. For example, in response to the 1987-1992 drought, many California communities, especially those in Southern California, took steps to develop alternative water supplies, such as recycled water and brackish groundwater, and to expand their knowledge of efficiency programs (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

Groundwater. During times of drought, users such as farmers and other landowners rely on groundwater to supplement surface water supplies. In California for example, until recently, this usage was generally unregulated. And although the state approved a piece of legislation in 2014 to prevent unsustainable groundwater use, according to the U.S. Geological Survey, it is estimated that it will take at least 50 years for the Central Valley's aquifers to naturally refill themselves (Halverson, 2015).

The situation in Australia and Cape Town is also complicated: in Australia, rates of groundwater extraction increased by about 100 percent between the early 1980s and the early 2000s, reflecting both the increased population size and commercial usage of groundwater stores. In Cape Town, to avoid spending in large-scale infrastructure projects, the city is building three small temporary desalination plants. However, it is drilling hundreds of bore holes, which risks using too much groundwater, as happened in California.

Integration. Water management systems in California are highly fragmented, with more than 400 water suppliers, each with at least 3,000 customer connections. This fragmentation makes it difficult to coordinate activities and reduces the economies of scale when developing demand management programs and initiatives, including communications (Public Policy Institute of California, 2017).

In Australia, to avoid fragmentation, the local 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 (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

Coordination and planning. The main lessons of the California drought in terms of urban drought planning and response are related to understanding how state and local water suppliers can best work together in the following interrelated areas:

1. Coordinating water shortage contingency planning and implementation (annual evaluations of supply and demand, allocation plans);
2. Fostering water system flexibility and integration;
3. Improving water suppliers' fiscal resilience;
4. Addressing water shortages in vulnerable communities and ecosystems;
5. Balancing long-term water use efficiency and drought resilience;
6. Fostering regional partnerships to improve water supply reliability;
7. Engaging the community and maintaining public support for water projects;
8. Implementing a "no regrets" approach: conservation, recycled water, groundwater, water loss, onsite water systems.

(Public Policy Institute of California, 2017)

Besides planning efforts, actions taken in response to recent droughts have included increased federal funding, policy changes and regulatory actions (NRDC, 2015; Taylor, 2016). For example, funding was provided for building new wastewater treatment plants and water efficiency upgrades (Taylor, 2016), and a mandatory 25% statewide reduction in urban water use was issued in 2015 (Office of the Governor Edmund G. Brown, 2015).

Additional responses include the adoption of new plumbing efficiency standards, updated ordinance to increase landscape water efficiency, requirements of management plans and efficiency management practices for agricultural water suppliers (NRDC, 2015). Moreover, outreach campaigns and rebate programs were funded to promote conservation (Taylor, 2016). However, an important area has been overlooked in California, as no water saving goal was set for the agricultural sector, which employs almost four times the amount used in urban areas– where significant water could be saved (NRDC, 2015).

Pricing. Water utility managers are sensitive to the reductions in sales that have occurred as a result of drought response actions. In California, concerns about short-term revenue losses are a significant barrier to expanding water efficiency programs. Yet efficiency investments are typically less expensive than building new supplies (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

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. Water utilities can benefit by improving their customer engagement efforts to build trust and educate users about water systems, the costs of managing those systems, and the long-term savings from efficiency investments. This was a missed opportunity in Australia, where public support was achieved by the sheer scale of communication and the urgency of the water saving investment, rather than a specific targeted campaign that explained the relative costs and benefits of different strategies (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

Pricing mechanisms such as drought surcharges or fee-bates (rewarding low water users and increasing prices for high water users) were implemented by SABESP in the MRSP. Customer representative groups raised important concerns about such mechanisms, with the potential to disproportionately affect poorer households, or renters who had less capacity to install water-efficient fittings compared to homeowners. However, following the drought, prices were increased anyway as a means of paying for large-scale supply infrastructure.

Data. 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. 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. (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

Innovation and (digital) technology. Smart Water Infrastructure Technologies (SWIT) have the potential to contribute significantly toward improved service delivery and efficiency of water services providers; reducing costs and water losses, streamlining operation and maintenance, and improving data and asset management in water utilities, allowing for information-based decision making (Arniella, 2017). Thus, the investment in these technologies is particularly relevant in terms of managing water supply.

SWIT include technologies such as active leak detection that coupled Management Information Systems and Pressure Management as a means of effectively monitoring water networks, easily identifying and repairing leaks, among others. As information can be complemented by water quality monitoring and hydrological data gathering systems, other examples include, Smart Metering or Water Quality, which can ensure with real-time information, a network's reliability. It can also reduce risk or help shape water consumption behaviors (Terwiesch, 2018).

In recent years, SWIT costs have been decreasing; it is therefore essential that water operators incorporate SWIT in their operating tools in the most cost-effective manner. This is particularly true in the case of SABESP, which has a research, technology development and innovation unit within the organizational structure. This unit allows SABESP to generate, adapt and apply technologies and other innovations related to service delivery, regulations and markets as a way to face operational challenges, including droughts. Because of its size, SABESP can also adapt, apply and replicate new technology benefiting from economies of scale, which might not the case for smaller utilities.

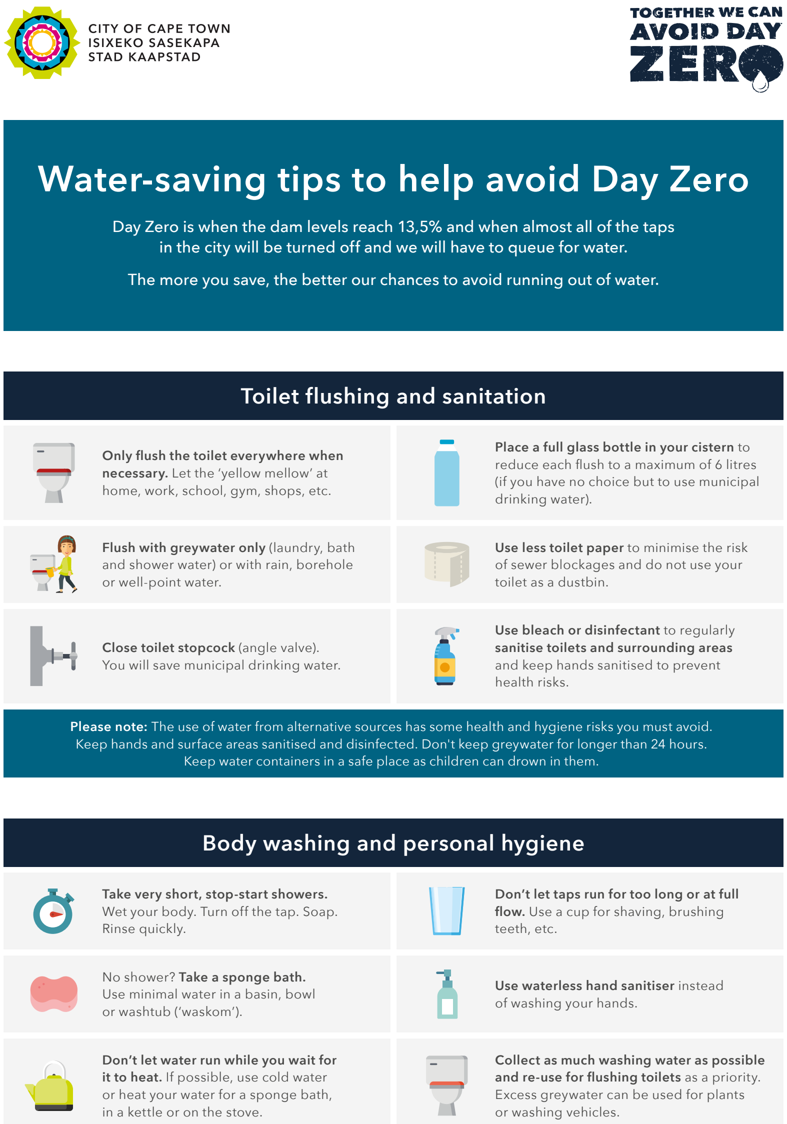
Behavioral change. Like Australia, São Paulo and California have reduced water demand through short-term conservation measures that rely on behavioral change, such as restrictions on the number of days lawns can be watered and calls for shorter showers and fewer toilet flushes.

In Australia, the Target 140 program was a highly innovative program using multi-strategy communication approaches to encourage reductions in household water use based on social marketing (Public Relations Institute of Australia, n.d.). That program was successful in part because it used research into the attitudes of the target audience to inform the campaign's design and determine how to best guide individuals along the various behavior changes to lead to action (Alliance for Water Efficiency, Institute for Sustainable Futures, University of Technology Sydney Pacific Institute, 2016).

The case of South Africa, which has drastically reduced consumption and pushed back Day Zero to 2019 is also an interesting example. The extraordinary savings (today, 50 lpd) have surpassed efforts made during the droughts in California (109 lpd in 2016) and Australia (166 lpd in 2010). The greatest cuts were made by high-income Cape Town households, which cut their average water use by 80%, while low-income families cut back by 40%. At the household level, messages targeted at Capetonians have focused, for example, on the adoption of water saving habits related to quick stop-and-start showers, with a bucket in the tub or captured water bucketed to toilets for flushing (Dixon, 2018). The mindset of the city's residents appears to have changed: there seems to be a sense of empowerment related to the capacity of living with less water and playing a part in a bigger collective effort associated with the future of the city.

Vigilant enforcement is also key. Law enforcement activities include stopping diverting mountain springs into their properties, washing down commercial refrigerated vehicles with fire hydrants or running informal car wash businesses in Cape Town's poor townships (Dixon, 2018; Sax et al., 2018).

Communication campaign in Cape Town to avoid Day Zero (link here)



In terms of alterative water supplies, recycled wastewater is a cheaper source than desalinization. However, because of the "yuck factor" -- the social conditioning that results in the belief that recycled water is dirty -- it is difficult for governments to embrace recycled wastewater as a viable solution for domestic consumption. California has already begun an awareness effort to change perceptions about recycled water. The Orange County Water District is using the hashtag #GetOverIt, for example (Rott, 2018). In the future, it will be interesting to follow behavioral change experiences geared toward efforts of socializing recycled water.

Overall, these types of conservation measures based on behavioral change represent a fast and relatively inexpensive way to meet reduction targets in water use and have helped reduce drawdown from surface water dams and groundwater aquifers (Institute for Sustainable Futures, 2007). However, to sustain positive behaviors throughout time, especially once the crisis is over, has proven to be a difficult challenge to face, regardless of the context.

CONCLUSION

Droughts are important agents of change for urban management of water supply and demand. These five droughts have left an imprint on water resource management and policies, particularly with regard to urban population growth and economic development. It is too early to know what the ultimate effects will be, but some initial indications can be gleaned.

SÃO PAULO. In São Paulo, the drought highlighted the significant reliance on the Cantareira system to supply water to the MRSP and the need to reduce dependency on a small number of water sources. SABESP is considering multiple strategies to bolster water supply over the coming decade by constructing interconnections with other reservoirs in São Paulo State for use during periods of low storage. However, there are limited opportunities to further expand water supply through water transfers.

SABESP also describes the need to implement a 12-year program to improve operating efficiency and reduce water losses mainly from leakages; non-physical water loss, which primarily results from inaccurate water meters installed at customers' premises and at the treatment facilities; and clandestine and illegal water use. Such tactical measures would reduce the baseline stress on the system, increasing the buffer between supply and demand.

While there are many external factors stressing the Cantareira system that managers cannot control, the development and execution of a transparent drought management plan that considers performance under highly stressful situations provides an important step toward the provision of reliable, safe and affordable water to the MRSP in current and future conditions.

CALIFORNIA. 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 serving 19 million people across Southern California, invested US$352 M in water efficiency (MWD 2015). 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 (Institute for Sustainable Futures, 2007).

It is important to note that California has drawn key lessons from past droughts, particularly the 1987-1992 drought, which have fundamentally changed the way the State manages water resources (Institute for Sustainable Futures, 2007). Hence, coordinating water shortage contingency planning and implementation is key for long-term water use and drought resilience, and could be further developed in a policy brief focusing on urban drought planning and response.

Long-term drought planning efforts have been demonstrated in California, where decades of investments in conservation and water reuse and the use of water markets and system interconnections allowed utilities more flexibility in the management of a significant drought (Hanak et al., 2015). The California drought also exposed weaknesses in the state's drought preparedness, such as inequities in the distribution of impacts (urban areas were well-positioned for drought whereas rural areas suffered impacts of dropping groundwater levels in private wells) and failure to develop plans for the environment (AghaKouchak, 2015; Hanak et al., 2015).

During and even before the drought, there was 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 is only beginning to recover after the recent downturn.

FIVE RECOMMENDATIONS

for water utilities facing water uncertainty

1.

GATHER GOOD DATA:

Gathering good data on water use at all levels -- down to the household level -- is critical to implement well-targeted conservation measures.

2.

COMMUNICATE WELL:

Clear and credible communication is crucial to ensure public support and participation. Working closely with communities and social leaders is also key to promote the adoption of positive behaviors to water conservation and efficient use, ultimately enabling the shift from a culture of water abundance to responsible demand.

3.

DIVERSIFY THE WATER PORTFOLIO:

This is critical to avoid relying on one source of water supply; this can include solutions less vulnerable to climate change, such as green infrastructure or adding non-conventional sources, such as wastewater reuse, into the water mix.

4.

COORDINATE, COLLABORATE AND PLAN:

Coordinating, collaborating, and planning among national and local government agencies is key to implement measures geared toward an optimal allocation of available resources.

5.

INNOVATE:

Smart water infrastructure technologies can significantly contribute to improving efficiency of water services providers by reducing costs and water losses, streamlining operation and maintenance, and improving data and asset management in water utilities, allowing for information-based decision making.

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ACRONYMS

ANA: National Water Agency of Brazil

AAPS: Authority for Fiscal and Social Control of Drinking Water and Basic Sanitation

CPUC: California Public Utilities Commission

DAEE: Department of Water and Energy of Brazil

EPSAS: Water and Sanitation operator in La Paz and El Alto

GTAG: Technical Advisory Management Group

LPD: liters per person and per day

MMAyA: Ministry of Environment and Water, Bolivia

MRSP: Metropolitan Region of São Paulo

MDRyT: Ministry of Rural Development and Lands, Bolivia

SABESP: São Paulo's Water and waste management company

SEA: Secretariat of Environment of the State of São Paulo

SENAMHI: National Service of Meteorology and Hydrology

SFPUC: San Francisco Public Utility Commission

USD: United States Dollars

IDB
Inter-American
Development Bank