On the Road to Independence:
The Case of Water Management in Singapore

Source: (PUB 2014a) "Local Catchment Water." Singapore. http://www.pub.gov.sg/water/Pages/LocalCatchment.aspx.

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Abstract:

Singapore is a small densely populated tropical island. While there is plentiful rainwater, Singapore is considered a water scarce country due to the limited land area available to catch water, lack of groundwater resources and increasing population (Khoo 2009). Singapore has taken this challenge as an opportunity and has developed a governance and institutional infrastructure to move from water scarcity to water sufficiency by 2061 through forward thinking and comprehensive planning. While once entirely reliant on Malaysia for its water supply, the country has transformed to become an innovator and a model for successful water management. It has been able to deliver one of the best urban water records in the world with access to water and sanitation reaching the entire population in less than fifty years (Tortajada, Joshi, and Biswas 2013).

Drawing on an analysis based on integrated water resource management principles, a range of factors are key to Singapore's success. This includes integrating water into development planning, building supportive institutional structures with the mandate to control, regulate and learn, adaptability and managing both supply and demand. It has successfully diversified its water supply through expanding and building reservoirs, importing water, desalination and water reuse. This has been combined with managing water demand through pricing, enforced water conservation measures and widespread public campaigning. The focus on a comprehensive, integrated water management approach provides a useful model for other urban areas around the globe to build systems based on their strengths and within their environmental constraints.

Introduction

If the world faces a crisis it will not be due to physical scarcities of water, but it will be due to sheer mismanagement of water – Professor Asit K. Biswas, winner of the Stockholm Water Prize

Water governance is a challenge for all urban areas in order to meet current and future needs. Water is a basic human right, necessary for maintaining ecological function and for industrial processes and is expected by users to be clear, clean and reliable (Gleick 2000). The majority of cities globally rely on imported water in order to meet these various consumption needs (Rygaard, Binning, and Albrechtsen 2011). This has been the case for most of Singapore's history as it has depended on Malaysia for the majority of its water supply. Today, Singapore has transformed its water system and begun its journey toward water independence.

The Republic of Singapore is a tropical urban island south of the Malaysian Peninsula. It is a small city-state of 718 km^2 with a dense population of 5.4 million (Singapore Department of Statistics 2014). While it receives ample rainwater during monsoon season, around 2,400 millimeters per year, there is limited space for water collection and storage (Tortajada 2006). Land area is further constrained by various competing uses including for housing, industry and business (Khoo 2009). Additionally, the island lacks groundwater resources. Given its ecological conditions, the United Nations ranks the country as 170 out of 190 countries in the world in terms of access to freshwater resources (Khoo 2009).

Singapore has taken this challenge as an opportunity and has developed a governance and institutional infrastructure to move from water scarcity to water sufficiency by 2061 through forward thinking and comprehensive planning. The country has been able to deliver one of the best urban water records in the world with access to water and sanitation reaching the entire population in less than fifty years (Tortajada, Joshi, and Biswas 2013). Through this process, it has also become an innovator and a model for successful water management. The Public Utilities Board, the national water agency, was awarded the prestigious Stockholm Water Industry Award for its "holistic approach to water resource management which made water use sustainable for different sectors of society in a unique and challenging urban island environment" (Stockholm International Water Institute 2007).

This case will provide an analysis of Singapore's water governance to examine how the country has made this successful transition. This case primarily focuses on drinking water, although Singapore's integrated approach includes other aspects such as flood management, sewage and storm water. Section 1 will focus on the history of water politics in the country. Section 2 will provide an overview of the current diversified water system. Section 3 will provide an analysis of institutional factors contributing to Singapore's water security. Section 4 will describe some of the future challenges to the water management system moving forward.

History of Water Politics

Singapore's water history is grounded within its development history. Singapore has relied on Malaysia for its water supply since 1927 (Goh 2003). In 1961 and 1962, two subsequent agreements were signed between the City Council of Singapore and the Government of the State of Johor to ensure consistent water supplies for the long term. The 1961 agreement gave Singapore 'full and exclusive right and liberty to impound and use all the water' from the Gunong Pulai Catchment, Tebrau River and Scudai River until 2011 (Tortajada, Joshi, and Biswas 2013). The 1962 agreement allowed Singapore to draw up to 250 gallons of water a day from the Johor River until 2061 (Tortajada, Joshi, and Biswas 2013). Under both these agreements Singapore pays less than 1 cent per 1000 gallons of water (Tortajada 2006).

Although these agreements were in place, Singapore faced water rationing in 1961 and 1963 due to inadequate infrastructure and water management (Khoo 2009). This left a strong impression on citizens and government of the tangible impacts of water access and the need to manage resources more effectively. As part of the response to these crises, the Public Utilities Board (PUB) was established in 1963 with authority over the supply and delivery of electricity, water and piped gas, which included managing these water agreements (Khoo 2009). In 1963, Singapore also became a part of the Federation of Malaysia. This union was short lived, however, and Malaysia asked Singapore to leave in 1965. Singapore was reluctant to split from Malaysia and its leaders questioned the country's ability to develop as a small island state.

Lee Kuan Yew, the Prime Minister, recognized that, in order to ensure Singapore's survival, developing a consistent source of water was a necessity. As part of its independence accord, it ensured that the water agreements were included in the separation agreement and guaranteed through an act of Parliament (Luan 2010). There was still tension, however, between the two countries and the Prime Minister of Malaysia, Prime Minister Tunku Abdul Rahman, threatened to turn off the water to Singapore if the country's foreign policy goals did not support Malaysia (Luan 2010). This placed Singapore in a precarious position, and water has been considered as a national security issue from the outset. In 1965, the country only had three reservoirs, which could only meet 20 percent of its needs (Tortajada, Joshi, and Biswas 2013), and therefore was highly reliant on Malaysia's water supplies.

Low hanging fruit and planning begins

The 1970s began a period of industrialization and urbanization through a combination of supportive legislation and infrastructure development. In 1971, a Water Planning Unit was established under the Prime Minister's Office to conduct a feasibility study for conventional and unconventional water sources to support the country's development trajectory. The unit wrote the 1972 Water Master Plan, which provided a blueprint to guide Singapore's long-term water resource planning (PUB 2009).

The Master Plan applied an integrated approach, which took into account the limitations and strengthens of Singapore's geography and institutions and the need to meet increasing water demands. This planning process began Singapore's trajectory to diversify water supplies and decrease its dependence on Malaysia. The plan targets included expanding catchment areas from 11 percent to 75 percent of the island and implementing pollution control to enable catchment area expansion (Tortajada, Joshi, and Biswas 2013). The plan was groundbreaking in that it included what was feasible within the short term while providing the policy framework for future innovation through introducing water reuse and desalination options for the first time. The research for the plan also demonstrated that, in contrast to previous studies, groundwater development was not a feasible option, given the low natural recharge rates, impermeable soils and lithology of the sediments, strengthening PUB's focus on other water sources (Tortajada, Joshi, and Biswas 2013).

Planning was tied to action. The government expanded the capacity of the existing reservoirs and catchment areas. The Seletar Reservoir was expanded 35-fold to create the Upper Seletar Reservoir and the Peirce Reservoir was expanded ten fold to create the Upper Pierce Reservoir (Tortajada, Joshi, and Biswas 2013). In addition, western rivers were dammed and the brackish water was pumped out to form reservoirs. The 1980s also saw the beginning of collecting rainwater through urban water catchments (PUB 2012).

The expansion of urban catchments was limited by extensive water pollution. In order to address the issue, stringent pollution control strategies and measures were adopted and enforced. In 1975, the Water Pollution and Drainage Act, monitored and regulated discharge into sewers (Tortajada and Joshi 2014). Other regulations followed which limited allowable effluents and required pollutants to be treated prior to discharge. Rules were also enforced to stop washing or bathing in the reservoirs and animals had to be removed from the area (Tortajada, Joshi, and Biswas 2013). The task to clean up the Singapore River was also taken up and in 1977, the Singapore government launched a 10-year program involving various government agencies to clean waterways (Khoo 2009).

Changing Institutional Structures

Water management in Singapore entered a new era characterized by a comprehensive approach in which institutions were further restructured, legislation continued being updated and the public was further engaged into water resources conservation activities. In 2001, the Public Utilities Board (PUB) was given ownership over the entire water system including water reclamation, sewage and drainage and drinking water (PUB 2012). The Sewerage and Drainage Act of 1999 mandates the PUB to maintain and manage public sewerage systems and storm water drainage systems, expanding its regulatory role (Tortajada and Joshi 2014). In 2004, the Environment Ministry was renamed the Ministry of the Environment and Water Resources, ensuring that environmental concerns were considered in water planning.

This institutional change supported the implementation of innovations in Singapore's water regime. In 2003, water recycling began. In 2005, the first desalination plant was built. In 2008, urban storm water collection began on a scale not seen in any other country (PUB 2012). These new water sources have been so significant that in 2011, Singapore decided not to renew the 1961 agreement and plans to not renew the 1962 agreement in 2060 as it expects to achieve water independence by that time (PUB 2012).

Overview of Water Management System

Water management in Singapore is based on Four National Taps in order to diversify its water resources. This includes imported water from Johor, local catchment water, desalinated water and NEWater. While local catchments and imported water meet Singapore's water needs, the government has proactively diversified its water sources.

Reservoirs

Singapore has increased the number of reservoirs from 3 in 1965 to 17 in 2011, increasing the overall catchment area from 11% to 67% (PUB 2012). It has adopted a long-term catchment approach to collect rainwater through an extensive network of 4340 miles of drains, canals, rivers and storm water collection ponds and to channel it to reservoirs for storage (Bhullar 2013). Singapore was among the first cities in the world to obtain drinking water from estuarine reservoirs and urbanized catchments in the 1970s and 1980s (Khoo 2009). Recently, catchment area has increased dramatically due to the construction of Marina Barrage, Punggol and Serangoon reservoir. The Marina Reservoir is an urban catchment that is equivalent to one-sixth the size of the country (Khoo 2009), greatly expanding water storage. The goal is to reach 90% catchment area in order to not waste any water that falls in the country through building a variable salinity plant, which will be able to treat brackish streams and small rivers along the shoreline (PUB 2014b).

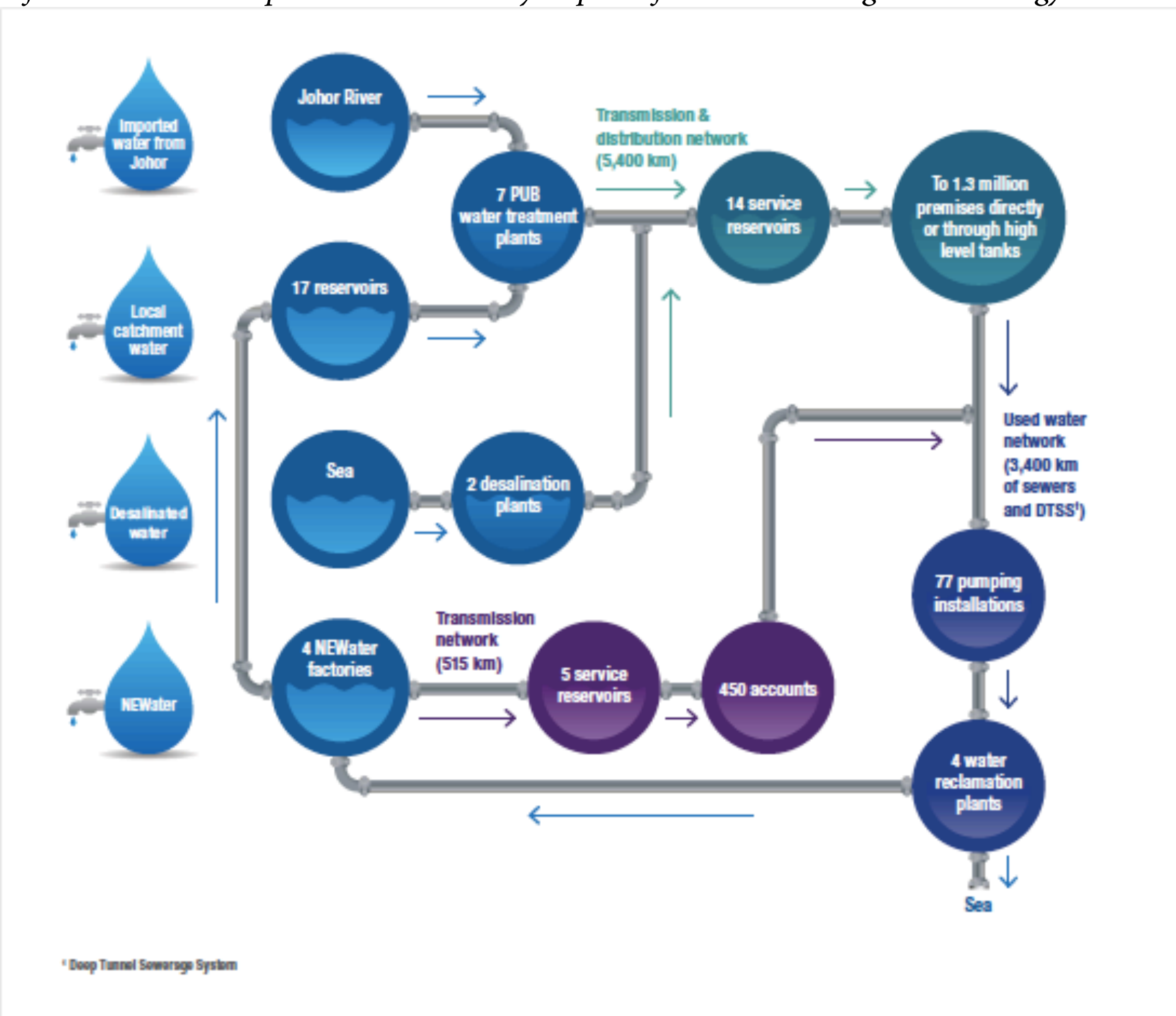
Desalinated Water

There are now two desalination plants in the country. The first plant was built in 2005 and relies on seawater and a reverse osmosis process (PUB 2012). This is one of the largest plants in the world and a second plant, the Tuaspring Desalination Plant began operating last year (PUB 2012). Currently, the plants cover 25% of demand through processing 100 million gallons a day (PUB 2014b). The capacity will continue to expand and by 2060, it will reach 30% of demand.

NEWater

NEWater or reclaimed water is treated sewage that goes through microfiltration, reverse osmosis and ultraviolet disinfection (PUB 2013). This is a reimagining of used water, as a resource to be recycled and re-used while also multiplying Singapore's water resources. It currently meets 30% of the demand in the country and plans to meet 55% by 2060 through expanding existing factories in Changi and Kranji and building a new factory in Tuas (PUB 2012). The process was first tested in 2000 and tested over two years and over 130,000 times to ensure its safety. The water exceeds both the World Health Organization and United States Environmental Protection Agency guidelines for water quality (PUB 2013). In fact, the water is cleaner than the treated water from the Johor River (Tortajada 2006). Now that the sewer system connects the whole island, all wastewater is collected and treated. It should be noted that night soil removal systems were in use until 1987 (PUB 2013), and therefore the move to sewer systems combined with water reuse is especially innovative. Currently, the water is being used for primarily industrial processes and air conditioning cooling for industrial and commercial buildings (PUB 2014b). About 3% of the water is used to top up reservoirs during extended dry seasons, which occurred from January to March 2014 (PUB 2013).

Diagram 1: Overview of the Water Management System
This diagram demonstrates the connections between the four water sources and the significant infrastructure development in the country as part of its water management strategy.



Source: PUB (2014) Available at: http://www.pub.gov.sg/general/Pages/WaterTariff.aspx

Factors for Success

The analysis below is based on the principals of Integrated Water Resource Management. Integrated Water Resource Management is most commonly defined as "a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership 2000). It has been promoted as the useful framework for water planning by scholars and practitioners. Integrated Water Resource Management involves the integration of various factors including development and water planning, water quality and quantity, different types of uses, demand and supply management and across time and governance scales (Biswas 2004). Singapore signed the Dublin principals based on Integrated Water Resource Management, and there has been a conscious effort to conform to its principals (Chen, Maksimovic, and Voulvoulis 2011). The section below presents an analysis of some of the features of Integrated Water Resource Management that are present in Singapore.

Integrating water into development planning

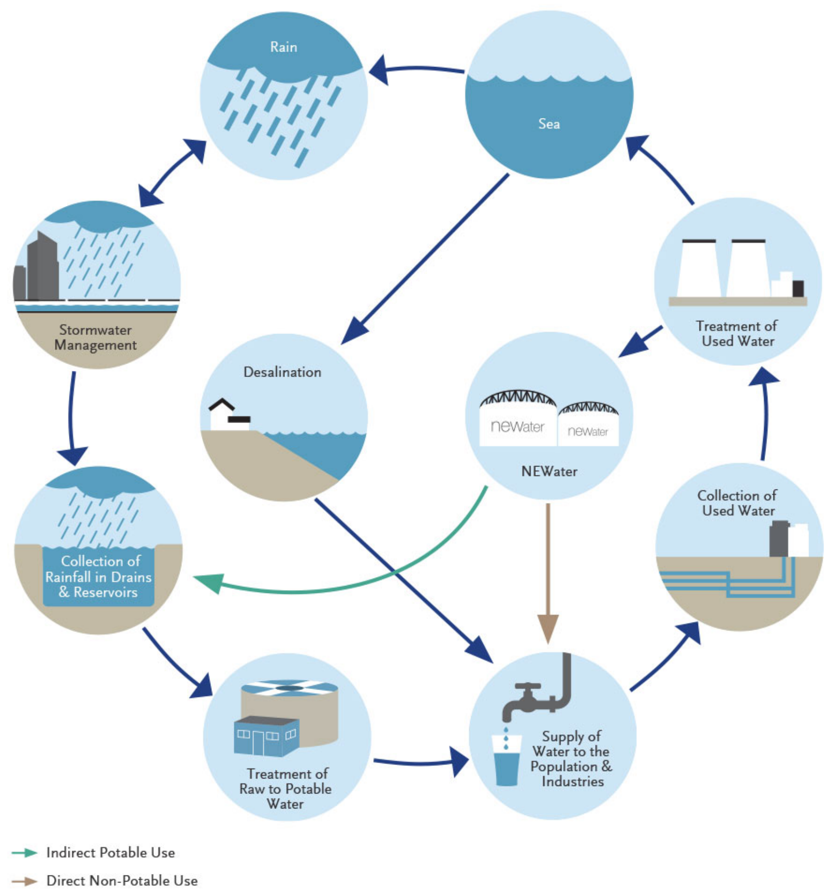
Singapore's water success has been grounded in a strong comprehensive planning regime. The case demonstrates how urban development requires uniting water, land, infrastructure and environmental policies and a commitment to sustainable development. Water has been integrated into wider development planning and has taken into account urban, commercial and industrial growth patterns. Planning has taken a long-term perspective providing a strong vision and the means to achieve it. The Water Master plan covered twenty years with demand projections estimated to 1990 (Tortajada, Joshi, and Biswas 2013). The plan and subsequent efforts since have combined land use, environmental and water concerns uniting the work of various agencies within the water planning agenda. This structure provided a means to address the issue with an understanding of both current and future water struggles within Singapore's larger development goals.

Closing the Water Loop and Supportive Institutions

The transfer of all components of water management to PUB facilitated the development of comprehensive policymaking and implementation. This includes protecting and expanding water sources, storm water management, desalination, demand management, community programs, catchment management and managing the outsourcing to the private sector. It is also literally closing the water loop, as PUB can reach its goal to capture every drop of rain, used water, and recycle all water more than once (PUB 2012), ensuring that no usable water is lost. Diagram 2 demonstrates how water is reused and retained within the system. Additionally, the combination of effective legislative frameworks and the strong regulatory enforcement has led to the success of utilizing urban catchments through ensuring physical infrastructure is maintained and connected to the main sewers, all wastewater is discharged into the appropriate sewage facilities and that there no water pollution due to improper discharge of trade effluent or hazardous waste.

There is also strong institutional coordination across agencies to support PUB's efforts. For example, in the clean up of the Singapore River, there was coordination between agencies responsible for land use planning, housing, environment, trade, industry and transportation. While this process took ten years and significant financial investment, the long term vision lead to a clean river and allowed for the separation of drainage and sewage systems.

Diagram 2: The Water Loop



Source: National Climate Change Secretariat (2012). Available at: http://app.nccs.gov.sg/nccs-2012/preparing-singapore-areas-of-work-in-progress.html

Adaptability

Pahl-Wostl (2008) has argued that adaptability is key to the success of integrated water resource management. This requires learning within policies and practices over time. Singapore is unique in that it has altered its policies and institutions to be able to respond the challenges as Singapore transitioned from a developing to a developed country. It also wrote the 1972 Water Plan with the outlook of considering advanced technologies that were not feasible at the time. In the 1970s following the plan, PUB began to study the use of desalination and water reuse technologies and found them to be too expensive and inefficient (PUB 2012). PUB however returned to these ideas as the technologies improved. It was through allowing for room for experimentation that it decided to apply these technologies later, rather than continuing with the status quo. New technologies were also tested through a small demonstration plant before scaling up innovations (Tortajada, Joshi, and Biswas 2013). PUB has also continued to monitor performance of these systems and to financially support research and development to inform future water technologies.

Managing supply and demand

The majority of countries address water supply issues through managing supply alone. Tortajada (2006) cited Singapore's supply and demand management as key to its success. Singapore has worked to protect its water sources in terms of quality and quantity over the long term, while also expanding available water sources through the Four National Taps strategy. In the 1980s, demand management started to have a more central role through promoting water conservation. This has occurred through pricing mechanisms, public education and community mobilization. Singapore has the highest water tariff in the region (Araral and Wang 2013). Water pricing includes the water tariff, water conservation tax and waterborne fee and sanitary appliance fee with different fee structures for households and non-domestic users. In the future, the government plans to charge the same price for potable water and used water given its value (Khoo 2009).

Other initiatives to promote conservation include mandatory water efficiency taps and toilets. Water conservation initiatives have been supported through water saving campaigns. This has included the 10-L challenge which encourages people to reduce their water use by 10 liters a day, water conservation week, learning centers for students and public engagement (Araral and Wang 2013). The campaigns have received international attention as NEWater received the UN-Water Best Practices Award for 2014 for its public communication and education (PUB 2013). Public engagement has been considered a success as daily per capita domestic water consumption decreased from 165 liters in 2003 to 156 liters in 2008 (Luan 2010). PUB plans to continue its water conservation focus and aims to decrease domestic water consumption to 140 liters per person per day by 2030 (Luan 2010).

Challenges

While Singapore has been able to innovate thus far, it is unclear if this pace can continue and accelerate to address rising energy prices, climate risks and changing demographics and needs.

Energy

Energy is one of the main challenges of water self-sufficiency around the globe (Rygaard, Binning, and Albrechtsen 2011). Singapore is no exception as a substantial amount of energy is required for pumping water, treating raw water and sewage effluent to produce NEWater and desalination. Desalination and NEWater are especially energy dependent due to the high pressures needed to force water through membranes and to remove salt. The price and availability of energy is a key cost for these water systems and global energy costs are expected to continue to rise. This leaves Singapore with a significant trade off because as it becomes more water independent, it becomes more dependent on imported energy. There are obvious political implications of this decision as energy can be procured from the international market while water supplies can only be economically imported from a single source, Malaysia.

Climate Change

According to a national assessment, climate change impacts in Singapore include an increase in average temperature, sea level rise and an increase in the intensity of weather variability. Government research has demonstrated that climate change could challenge its water management strategies (NCCS 2014). In particular, there is concern that droughts could affect the reliability of Singapore's water supply and that intense rainfall could lead to flash flooding. There has been increased evidence that climate change will require more flexible water management systems (Huntjens et al. 2012). Given the extensive hard infrastructure, it is likely that there will have to be changes to address emerging risks and have a more iterative management approach. At the same time, some technical aspects are being addressed; NEWater and desalination are not rainfall dependent and could fill reservoirs when rainfall is low.

Urbanization, Population Growth and Increased Demand

Singapore has gone through dramatic development changes as the population has grown from 1.8 million in 1965 to 5.1 million people in 2011 and per capital GDP has exploded from $1,580 to $63,050 during the same period (Tortajada, Joshi, and Biswas 2013). Water consumption has increased 12.2 times since 1965. These trends are continuing. Water managers expect that in 2060, water needs will double from 2011 to 3,460,00 m^3/day (PUB 2013). In a recent population white paper (2013), the population is expected to reach around 6 million by 2020 and between 6.5 and 6.9 million by 2030. This will bring enormous challenges for water systems to address increasing demands that follow increasing population and economic growth.

Conclusion

Singapore is on its way toward becoming water sufficient by 2061. This outcome could not be more unexpected given that it is a densely populated urban island that had easy access to substantial water resources across the strait in Malaysia. Singapore has become an innovator and model in urban water management. This success is due to a range of factors including integrating water into development planning, building supportive institutional structures with the mandate to control, regulate and learn, adaptability and managing both supply and demand. It has successfully diversified its water supply through expanding and building reservoirs, importing water, desalination and water reuse. This has been combined with managing water demand through pricing, enforced water conservation measures and widespread public campaigning. The focus on a comprehensive, integrated water management approach has provided the active test bed for new ideas and the ability to implement them effectively.

While part of Singapore's ability to implement effective water policy is due to its unique governance structure as a city-state. There are various institutional, technical and innovative factors, which are applicable to other urban areas. It is essential for cities to manage their water as a finite resource that is integral to their overall development planning. As the world shifts to become more urbanized, the lessons from Singapore have large implications is moving toward a more sustainable approach to water management.

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