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Foreword

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Water is essential for life. Without water, there would be no life on Earth.

Today, one in 10 people – more than 700 million – lack access to a basic drinking water service. One of the Sustainable Development Goals of the United Nations is universal and equitable access to safe and affordable drinking water by 2030.

With expanding global population and agricultural and industrial needs, the demand for clean water is ever increasing. The challenges of water security are compounded by climate change, which will bring more frequent and intense droughts and floods, affecting the availability and distribution of water resources.

To ensure water security in a changing climate, good water management and governance are critical. Good policies need to be backed by effective implementation. Strong support from public agencies, businesses, non-governmental organizations and members of the public is also needed to successfully implement such plans. Everyone needs to work together to tackle our water challenges.

As a small, highly urbanized island state in South-East Asia, Singapore has embraced a holistic approach to water security. One of the most water-stressed countries in the world, Singapore has developed a diversified water supply with its Four National Taps: water from the local catchment, imported water, high-grade reclaimed water (known as NEWater) and desalinated water.

Our water journey began in the early days of independence, over 50 years ago. Our founding Prime Minister, Mr Lee Kuan Yew, recognized that water security was key to Singapore's survival, and famously declared, 'Every other policy had to bend at the knees for our water survival.' He tasked PUB, Singapore's National Water Agency, to collect every drop of water and make it potable.

To realize our first National Tap, Mr Lee called for the clean-up of all rivers and streams in Singapore, including the Singapore River. The massive clean-up operations, which involved resettlement of many homes and businesses, took a decade to transform the Singapore River from an open sewer into a beautiful waterway. These clean-up efforts paved the way for the creation of Marina Reservoir in 2008, an iconic reservoir in the heart of our city. The Marina Reservoir has made Singapore one of the few countries in the world to tap urban stormwater for its water supply. Overall, two-thirds of our island serves as a water catchment.

PUB began researching water reclamation and desalination in the early 1970s. Although the production process was initially expensive and unstable, PUB persisted over several decades and eventually successfully added NEWater and desalinated water as National Taps in 2003 and 2005, when technological breakthroughs made these

economically viable and reliable. With the successful recycling of used water, Singapore is one of the few countries to have closed the entire water loop, embracing a circular economy approach.

These efforts to enhance our water supply must be complemented by good water demand management. Water needs to be priced right to reflect the latest cost of water supply and its scarcity value. At the same time, PUB has consistently promoted water conservation through the years and encouraged homes and industry to use more efficient water fittings, equipment and processes. Household water consumption per capita has fallen from 165 litres per day in 2003 to 141 in 2018, and is targeted to fall further to 130 by 2030.

We are leveraging technology to manage water demand. PUB is rolling out the first phase of its Smart Water Meter Programme, which will see the installation of 300,000 automated water meters by 2023. Customers will be able to monitor their daily water usage and receive high usage notifications, to encourage them to conserve water.

Our water infrastructure must be continuously maintained and upgraded. To reduce water losses during transmission, PUB regularly replaces older pipes and uses the latest resilient materials to increase the durability of pipes. Last year, we completed the upgrading of one of Singapore's oldest water treatment plants, at Choa Chu Kang, with advanced and efficient treatment processes, such as ceramic filtration membrane and ozone-biological activated carbon treatment.

To help us tackle the water challenges arising from climate change, we will continue to invest heavily in research and development. PUB is working with partners on electrodeionization technology and biomimicry, which could halve the energy required for water desalination. PUB is also deploying data analytics and sensors to identify and anticipate issues ranging from transmission losses to flash floods. These investments have catalyzed a thriving water industry, turning Singapore into a major hydro-hub for the testing and implementation of new technologies.

Looking ahead, Singapore will harness synergies across water and other sectors such as waste, energy and food. When completed in 2027, Tuas Nexus will be the world's first greenfield development to integrate a water reclamation plant and an incineration plant. Tuas Nexus will co-digest used water sludge and food waste into biogas, which in turn will help power the plant. By expanding our circular economy approach, we hope to maximize Singapore's resource resilience and contribute to a sustainable future.

This Festschrift or special issue of the *International Journal of Water Resources Development*, prepared by Dr Cecilia Tortajada and Professor Eduardo Araral, commemorates the 80th birthday of Professor Asit Biswas. Professor Biswas is well respected internationally and one of the world's leading water experts. He founded this journal in 1985 and was its Editor-in-Chief for 29 years; currently, he serves as Editor. Professor Biswas is strongly committed to achieving a water-secure world and has advised many policy makers, including those in Singapore. In recognition of his contributions over several decades, he was awarded the prestigious Stockholm Water Prize in 2006.

Professor Biswas is a valued friend of Singapore and has been advising the Singapore International Water Week, a global platform to share and co-create innovative water solutions, since its inception in 2008. Over the years, he has helped garner strong participation in the Water Week to foster productive discussions of our water challenges.

In honour of Professor Biswas's outstanding and inspiring work, more than 20 prominent leaders of water utilities and the public and private sectors, as well as outstanding academics, have contributed to this Festschrift. This issue will be a valuable resource in humanity's journey to achieve water security, and it is a fitting tribute to Professor Biswas on this auspicious occasion.