THE ILLUSION OF PLENTY

HONG KONG'S WATER SECURITY, WORKING TOWARDS REGIONAL WATER HARMONY

ADM CAPITAL FOUNDATION
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WYNG FOUNDATION

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About ADM Capital Foundation (ADMCF)

Established in 2006, ADMCF is an impact driven foundation with a focus on environmental issues. Based in Hong Kong, the Foundation provides strategic funding and other support to organisations that work towards environmental health and conservation in Asia in a manner that is sustainable and sensitive to local cultures. Specifically it works towards resolving challenges in relation to marine biodiversity, water security, air quality, wildlife trade and forestry conservation finance.

About Civic Exchange

Civic Exchange is an independent, non-partisan, Hong Kong-based public policy think tank established in 2000. With a vision to shape a liveable and sustainable Hong Kong, Civic Exchange's mission is to advance civic education and engage society to influence public policy through research, dialogue and development of practical and sustainable solutions. Civic Exchange undertakes research in three major areas: Air Quality, Nature Conservation and the Urban Environment, with an overarching framework of promoting Wellbeing.

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Preface

Water sustains life and facilitates social and economic development. It is vital to our existence, and yet little attention is paid to the precarious nature of Hong Kong's long-term water security. The most recent Policy Address by Chief Executive Leung Chun-ying in January 2017, illustrated how low water issues fall on Hong Kong's political agenda, despite the stark reality that Hong Kong is more water scarce than parts of the Middle East and Africa.

'The Illusion of Plenty: Hong Kong's Water Security, Working Towards Regional Water Harmony' examines the challenges Hong Kong faces in managing its water sustainably and responsibly. As regional populations burgeon, industries expand and the climate system is increasingly disrupted, innovative strategies must be formulated to ensure that water continues to flow through Hong Kong residents' taps.

This report presents the most up-to-date perspectives and data, based on numerous interviews and a thorough review of documents, articles and reports spanning more than two decades. It provides information on the complex relationships and policies governing water resources in Hong Kong. It identifies innumerable shortcomings within the existing management structure, regulations, tariff schemes, supply network and long-term strategies of the Hong Kong government.

This report is intended to provide a clear insight into the severity of water scarcity in Hong Kong, and the challenges the city faces in protecting this "precious" resource. Ultimately, it explores a range of strategies, including some that that have been successfully adopted elsewhere, which could contribute to regional water harmony.

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Acronyms and Abbreviations

AC	Audit Commission
ACWS	Advisory Committee on Water Supplies
ACQWS	Advisory Committee on the Quality of Water Supplies
ADMCF	ADM Capital Foundation
AMR system	Automatic Meter Reading system
ANFA	Average Net Fixed Assets
BD	Buildings Department
BEAM	Building Environmental Assessment Method
CFS	Centre for Food Safety
CLG	Customer Liaison Group
CMP	Crisis Management Plan
COI	Commission on Investigation
CO_2	Carbon dioxide
CSD	Correctional Services Department
C&SD	Census and Statistics Department
CSSA scheme	Comprehensive Social Security Assistance scheme
DCP	Drought Contingency Plan
DevB	Development Bureau
DJ	Dongjiang
DMA	District Metering Area
DongShen Agreement	Dongjiang-Shenzhen Water Supply Agreement
DRBA	Dongjiang River Basin Authority
DSD	Drainage Services Department
DWR	Department of Water Resources (of Guangdong Province)
ENB	Environment Bureau
EMSD	Electrical & Mechanical Services Department
EPD	Environmental Protection Department
ESG	Environmental, Social, and Governance
FEHD	Food and Environmental Hygiene Department
FWCT Scheme	Scheme for Wider Use of Fresh Water in Evaporative Cooling Towers for Energy-efficient Air-conditioning Systems
GDH	Guangdong Holdings Limited
GHG	Greenhouse gas
GI	Guangdong Investment Limited
GLD	Government Logistics Department
HA	Housing Authority
HD	Housing Department
HKGBC	Hong Kong Green Building Council
HKEx	Hong Kong Exchange
HKO	Hong Kong Observatory
HKU	University of Hong Kong
HVUSSS	Happy Valley Underground Stormwater Storage Scheme

Acronyms and Abbreviations (cont.)

ITB	Innovation and Technology Bureau
INMS	Intelligent Network Management System
IEP	Integrated Education Programme
IPCC	United Nations Intergovernmental Panel on Climate Change
JO	Joint Office on Water Seepage
LCSD	Leisure and Cultural Services Department
LegCo	Legislative Council
LOOP	Low-carbon Office Operation Programme
LOP	Lok On Pai
MEWR	Ministry of the Environment and Water Resources (of Singapore)
MRs	Meter readers
NEA	National Environment Agency (of Singapore)
NRW	Non-revenue water
OECD	Organisation for Economic Co-Operation and Development
OHCHR	Office of the United Nations High Commissioner for Human Rights
PAC	Public Accounts Committee
PRD	Pearl River Delta
PRH	Public Rental Housing
PU	Prosecution Unit (of the Water Supplies Department)
PUB	Public Utilities Board (of Singapore)
R&R programme	Replacement and Rehabilitation programme
SARS	Severe Acute Respiratory Syndrome
TES	Trade Effluent Surcharge
TKO	Tseung Kwan O
TWM Strategy	Total Water Management Strategy
UNDP	United Nations Development Programme
VPN	Virtual Passport Networks
WACS	Water Air Cooled Systems
WaterCo	Guangdong Yue Gang Water Supply Company Limited
WELS	Water Efficiency Labelling Scheme
WHO	World Health Organization
WIN	Water Intelligent Network
WSD	Water Supplies Department
WSP	Water Safety Plan

Glossary

Consumption	Volume of water consumed directly by the consumer. This volume no longer includes that water which is lost from the network.
Freshwater	Water with a low concentration of salt (below 1%), essential to nearly all life on Earth. In liquid form it naturally occurs in rivers, lakes, ponds, and underground, in aquifers and subterranean streams.
Greywater	Comparatively clean wastewater for example from appliances such as baths, sinks, and washing machines.
Raw water	Natural water that has not been treated or purified.
Reclaimed/ recycled water	Former wastewater or sewage that is treated, so as to remove solids and pollutants.
Seawater	Water from the ocean or a sea. On average, seawater throughout the planet's oceans has a salinity of approximately 3.5%.
Supply	Volume of raw water imported or stored, ready for treatment and distribution. This volume is calculated before any losses from the network.
Unmetered/ Non-revenue water	Water that is not metered or charged for. A shortfall in the quantity of water between that recorded before treatment and that recorded by the household or building meters.

Financial conversion rates:

US$1 = HK$7.76	HK$1 = US$0.13
RMB 1 = HK$1.16	HK$1 = RMB 0.86
S$1 = HK$5.56	HK$1 = S$0.18

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EXECUTIVE SUMMARY

Water under Severe Stress Worldwide

Climate Change: A Global Threat to Water Security

Only 2% of the world's water is freshwater - a fundamental resource needed for growing food, producing energy, and our very survival. Water availability per capita is decreasing internationally, and today 25-39% of the world's population is estimated to live in watersheds exposed to scarcity. By 2050, over half of the world's population could be subject to water stress.

Climate change has exacerbated this situation and today is one of the biggest challenges humanity faces globally. The Intergovernmental Panel on Climate Change (IPCC) indicated, in its Fifth Assessment Report, that for every 1°C increase in global temperature, a further 7% of the Earth's population would face decreases in freshwater availability. Experts predict that temperatures could climb by as much as 7.4°C above pre-industrial levels by the end of the century, under a business-as-usual scenario.

Rising temperatures impact variables throughout the atmospheric and oceanic systems meaning water availability (including quantity, quality and seasonality) will change. This, in turn, could exacerbate droughts and floods. At the same time, the frequency and intensity of precipitation will increasingly vary and rain, rather than snow, will fall more frequently. In response, soil moisture and groundwater levels will change. More intense typhoons, sea level rise and migrating rainfall patterns are only a few of the most imminent and expected consequences.

Projected Population Growth Makes the Situation Even More Challenging

Compounding the disruptions brought by climate change, growing populations are putting water resources under more stress. It is projected that the world's population will reach 7.71 billion by 2020 and 9.55 billion by 2050. The intensity of consumption will be especially striking in Africa, Asia and South America where the majority of population growth will occur. The projected increase in population will inevitably lead to an increase in water, food and energy consumption, thus further increasing water demand in the future.

Additionally, factors such as migration, technological advancement, infrastructure and shifting land use patterns will affect water availability in the future. Water security is, therefore, high on the political agendas of many countries, jurisdictions and cities.

Pressure Mounting in the Pearl River Delta

In the Pearl River Delta (PRD), which includes parts of Guangdong Province, Hong Kong and Macau, the consequence of disrupted climate regimes has become a major concern, leading to uncertainty around long term water availability. Indeed, some researchers believe that river flows in the PRD, could decline by as much as 24% by the 2070s. However, observations on the PRD's second largest river, the Dongjiang, which supplies water to seven of China's major cities as well as the majority of Hong Kong's freshwater, indicate that the system remains relatively stable and resilient. Vast engineering works, such as the Xinfengjiang Reservoir in Guangdong Province, have reportedly bolstered the capacity of the basin, with sufficient stores to offset all but the most infrequent and extreme multi-year droughts.

The Dongjiang has, however, been beleaguered by pollution from aggressive industrial expansion and rapid urbanisation throughout Guangdong and the surrounding regions. The economy of the province now accounts for 10% of China's GDP. Population in the PRD has also boomed to the extent that more than 20,000 diversion projects now syphon water from the Dongjiang, sustaining more than 40 million people.

In order to supplement growing demands, authorities throughout China are continually seeking to improve their water management strategies. The Xijiang is the western tributary of the Pearl River, and southern cities have turned to this watercourse to make up for deficits elsewhere. However, this so-called 'Golden Waterway' has experienced significant shortages of its own, notably stranding 900 shipping vessels in 2011 as runoff declined by 30%.

In spite of the prevailing uncertainty as to the sufficiency of long-term water supplies from the Dongjiang, it is clear that water scarcity and drought are risks that need to be recognised by Hong Kong's government as well as its public.

Hong Kong's Water Security Challenges

Despite abundant rainfall, seasonal typhoons, large impounding reservoirs and a water supply from China that has remained largely uninterrupted for over 30 years, Hong Kong itself is more naturally water scarce than parts of the Middle East and Africa. Defying this stark reality, water security is worryingly low on the Hong Kong government's agenda. Yet, with the mounting pressures of population growth, thirsty businesses, changing land uses and climate change, it has never been more important to consider the future of Hong Kong's water security.

The Historical Context: A Legacy of Inertia

In 1965, the Hong Kong government negotiated a deal with the Guangdong authority to supply Hong Kong with freshwater, and in doing so, established a connection with the Dongjiang. This supply first exceeded the yield from Hong Kong's local catchments in the mid-1980s and Hong Kong has not rationed its water since May 1982.

This agreement has been maintained for over five decades, with Hong Kong receiving up to 80% of its supply from China in recent years. The security provided by the Dongjiang has been invaluable, and yet it has also hindered local innovation and attempts to diversify the system for more than half a century.

Hong Kong imports hundreds of millions of cubic metres (m^3) of raw water from China every year, and the regional demand placed on the Dongjiang surged past the level deemed "ecologically safe" in 2004. In response, China ushered in an era of strict allocation policies, and in 2008 Hong Kong's introduced its 'Total Water Management' (TWM) Strategy. The TWM Strategy was formulated by the Water Supplies Department (WSD) with the intention of diversifying Hong Kong's water portfolio, providing a catch-all solution to water disruption from climate change and as a strategy to "enhance Hong Kong's role as a good partner" in the PRD.

Despite the TWM Strategy, at the broadest scale no water policy has been advocated or established and little progress has been made in addressing long-term water security. Nevertheless, the Strategy is a necessary part of any plan to enhance Hong Kong's resilience and reduce Hong Kong's demand on the natural systems of the PRD. The rationale and motivation for such a transition is pragmatic and should be centred on Hong Kong's desire to be a good neighbour. As a major city and economic power within the PRD, the effects of Hong Kong's decisions on water ripple across the region, with consequences for all.

Hong Kong has the capacity and resources to become a regional leader in water management and resilience, and it is vital that the city harmonises water usage with its neighbours by contributing to the sustainable development of the Delta and aligning Hong Kong with the progressive water policies championed by China.

Supplying Hong Kong: Reliance on the Pearl River Delta

Today, the majority of Hong Kong's water continues to flow from Guangdong Province. Hong Kong has exclusive rights via the so-called 'DongShen Agreement' to as much as 820 million m^3 of this raw freshwater each year. This comprises the bulk of the 1.25 billion m^3 of fresh and seawater consumed by the city's population annually.

Negotiated every three years between the governments of Guangdong Province and Hong Kong, the Agreement is overseen by Guangdong Investment Limited (GI), in which the provincial government has a majority stake. The deal is lucrative and directly benefits GI's shareholders, with the water it supplied to Hong Kong providing approximately 46% of GI's revenue in 2015.

Under the administration of GI, the unit cost of Dongjiang water has been steadily increasing with the annual payment rising from HK$2.43 billion in 2001 to HK$4.22 billion in 2015. Hong Kong now pays 3.3 times more than neighbouring Shenzhen and Dongguan, despite demanding 34% less water. Whilst this appears imbalanced at first, the reality is that Hong Kong should be paying a high price for a guaranteed supply of this valuable resource. Indeed, contentious though it would be, it would be reasonable to expect Hong Kong to pay an even higher price for this water, with the aim of contributing financially, through 'water resource fees' and eco-compensation schemes, to ensure high water quality and conservation efforts in upland areas.

The major weakness of the current 'Package Lump Sum Deal,' the payment mechanism of the DongShen Agreement, is that Hong Kong must pay for all of its agreed allocation, regardless of how much water it actually imports. The approach has contributed to disincentivising conservation, whilst annual withdrawals have remained under the 820 million m^3 ceiling.

Hong Kong Government Performance: Uninspiring Over Two Decades

The WSD is the sole water authority managing water supply and regulating potable and flushing water quality in Hong Kong. Ensuring an uninterrupted supply of good quality drinking water to Hong Kong residents is the department's primary focus. The engineering mind-set that has allowed WSD to achieve this has undoubtedly benefited Hong Kong. However, neither the WSD nor its policy bureau – the Development Bureau – have cultivated the important socio-economic or environmental expertise that would enable a comprehensive policy and strategic approach to ensuring Hong Kong's long-term water security.

Part of the challenge for the WSD in implementing a robust, accountable series of policies and initiatives, is the way in which the government operates. According to investigations conducted by independent government agencies, the Department has been underperforming for nearly two decades in multiple areas.

Due to the traditional vertical structure of government, inter-departmental operations and collaboration are necessities that can rapidly become complicated. Work as basic as maintenance can require coordination and collaboration between numerous government departments and bureaux, each of which operate in compliance with different ordinances and objectives. Insufficient co-ordination and poorly defined responsibilities contribute to the lack of a coherent water policy .

Management of the water system has been further complicated by the shortcomings in the WSD's existing protocols and remit, which does not ensure the integrity and safety of water to the point of delivery, but only to the point of connection.

Wasting a Valuable Resource: Non-Revenue Water

The WSD manages a distribution network of pipes extending around 8,075 km (81% freshwater; 19% seawater) – a distance equivalent to a flight from Hong Kong to Cairo. The network has, however, been challenged for decades. By 2000, it was clear that a quarter of Hong Kong's water was lost from government-maintained pipes before it could reach its intended destination.

Poor, often retroactive management of the distribution network has been an ongoing issue. From 2000 to 2015, the government mains network has been vastly improved, through the WSD's 'Replacement and Rehabilitation' (R&R) programme, with leakage reduced by 10%. Nevertheless, it remains considerably higher than the rates observed in similarly wealthy and developed world cities.

In 2013 (the most recent year disaggregated leakage data was available), 17% of freshwater was still being squandered as it flowed through government mains. A further 15% was lost through a combination of leakage from private mains (inside services), illegal extraction, as well as inaccurate metering – all considered 'non-revenue water'. Whilst it is unclear precisely how much of Hong Kong's freshwater is lost to each of these mechanisms, it is estimated that as much as 11% could be due to leakage from private premises.

Overall, the 31.6% of freshwater unaccounted for in 2013 potentially representing HK$1.35 billion in lost revenue. By 2015, this figure had risen to 33%. Between 2004 and 2015, the WSD may have lost as much as HK$17 billion of potential revenue from its unmetered freshwater alone.

Reckless Overconsumption

Despite the inadequacies of the network, the WSD has successfully met local demand for over three decades thanks to supply from the Dongjiang. Unfortunately, this impressive record has fostered a false sense of security and an illusion of plenty among Hong Kong's consumers. A study of 48 major international cities found that Hong Kong is one of the highest per capita water users globally and has experienced an exceptional rise in domestic water demand since 1990. This has been fostered in part by the perception of unlimited supplies.

While over half of Hong Kong's freshwater is consumed by the domestic sector, poorly-directed and seemingly ineffective attempts have been made by the WSD to rein in domestic consumption. Campaigns have been well-intended, yet largely

uninspired and, ironically, have been accompanied by rising demand. In 2011, the government's 'Domestic Water Consumption Survey,' which aimed to glean a holistic impression of how water is used, was half-hearted, with the department failing to design a robust study methodology. Furthermore, the WSD has neither repeated nor appeared to have advanced its investigations on this front over the subsequent six years.

Beyond water for domestic use, the remainder of Hong Kong's water supply is dedicated to non-domestic users: largely commercial consumers and the government. A quarter is used by service trades (e.g. catering, hotel sector), and the remainder by industry (6.2%), construction and shipping (2.4%), government establishments (4.4%) and as flushing water (7.9%). Combined, these consumed 423 million m^3 of freshwater in 2015. Government establishments used 10% of this.

Operating in the Dark

One of the greatest barriers to addressing overconsumption, and thereby Hong Kong's water security, is the opacity of domestic and non-domestic consumption patterns, and user behaviour. To this end, the WSD is operating in the dark, striving to manage a "precious resource" without a full picture of its use and loss. For example, water consumption of the highly varied enterprises and activities incorporated within the 'non-domestic sectors' is rarely disaggregated, examined, or explained.

Many major water users in Hong Kong depend on the extraction of a publically subsidised resource, but are not obliged to disclose consumption figures. This situation has resulted in large voids in public knowledge and complicated attempts to improve the efficiency of water allocations and consumption. For example, Ocean Park and Watsons Water are known to consume large quantities of water, yet their usage has never been publically disclosed. They are unlisted and therefore not bound by disclosure requirements, such as the recent 'Environmental, Social and Governance' (ESG) requirements of the Hong Kong Exchange. As long as heavy users are permitted to extract with no accountability, reform will be problematic.

Whilst gaps remain in the WSD's database, it will remain challenging to create targeted policies and initiatives to address consumption. In 2015, the WSD piloted its 'Smart Metering System' smartphone app, providing near real-time data and a record of recent consumption. Under its broad scheme of developing a 'Water Intelligent Network,' a component of the government's plans to transition Hong Kong into a 'smart city,' the department aims to install smart water meters across Hong Kong. Among other strategies, this innovation could play a major role in reining in consumption, and should be adopted sooner rather than later.

Lack of Rational Water Pricing

Water is arguably the world's most underappreciated and undervalued resource. In Hong Kong, this view has been reinforced by a low pricing structure facilitating increasing overconsumption. Hong Kong's waters tariffs are tiered, based on the volume of water consumed in blocks (Tier 1 to 4). Since 1995, every household account has received a free allotment of 12m^3 (12,000 litres) of potable water (Tier 1) to use over a four-month period. Consumption beyond this free allocation is priced at some of the lowest rates in the world, such that the most expensive Tier 4 tariff (HK$9.05 per m^3) levied for consumption in excess of 62m^3 of water every 4 months, covers less than 60% of the cost of production, based on 2015 figures. Perversely, the government refers to this low price as its "punitive rate".

The current tariff system has resulted in 70% of domestic water being purchased at a government-subsidised price. This has bred complacency as well as hostility towards any suggestion of reform. The Chinese government recommends pricing water at 2.5% to 3% of household income, which is ten times more than Hong Kong's current ratio.

Lack of a rational pricing policy has also contributed to a recurring annual deficit in the WSD's budget, which, in 2015, was over HK$1 billion. The WSD has sought to reform its tariffs in the past, but this has been opposed persistently by the Legislative Council (LegCo). The main argument championed by LegCo is based on sparing the city's poor from any additional hardship. As of 2015, there were nearly one million people in Hong Kong living below the poverty line, even as the government's budgetary surplus grew to HK$860 billion.

The answer, however, is not to reject reform but develop practical solutions that protect the financially disadvantaged.

Striving toward a Water Secure Future

Hong Kong is intrinsically bound to China, not only through economy, politics, history and geography, but also, critically, through water. As part of the PRD, and being reliant on its water resources, Hong Kong has a responsibility to manage its water supply effectively and with foresight. The Administration has the opportunity and a moral, social and financial obligation to lead Hong Kong towards a future in which the PRD's water supply is secure.

More importantly, Hong Kong has sufficient means, capability and reason to tackle the innumerable challenges plaguing its water system. Taking prompt, efficient and impactful actions on charting a water policy for Hong Kong, reducing the city's demand for water, and diversifying and optimising water supply should be a priority.

Detailing its "Hong Kong 2030+" vision, the government cited the existing TWM Strategy as a component of its plans to develop an integrated smart, green and resilient infrastructure system. However, in order to achieve this, Hong Kong must review, develop and implement a strategy that is truly capable of adapting to changing circumstances. It should take a holistic approach that addresses climate risk and energy as part of its water management and encompasses plans to deploy innovative and creative solutions.

Establish a Comprehensive Water Policy, Strategy and Targets

The time has come for well-coordinated, ambitious and concerted efforts to deliver a policy and supporting strategy that will clarify commitments, establish clear goals and key performance indicators, as well as ambitious timeframes relative to our water security. This should incentivise expeditious and innovative solutions, clarify the ramifications for its own and others' failure and non-compliance, and be subject to regular review.

If the Hong Kong government is to continue promoting local freshwater as "one of the safest water supplies in the world", it must also change its current source to connection point policy. This means taking steps to honour the WSD's 2006 pledge stating its commitment to implementing "measures and practices to ensure the quality and safety of drinking water to consumer beyond the connection points." This is an important step in enhancing the integrity of the entire water system, especially with a view to minimising potential losses from private premises.

Improving Governance and Management

Governance reform is essential to ensuring that management of Hong Kong's water resources is unified under a policymaking body that has the broader skills, expertise and authority to develop and implement a comprehensive water policy and strategy. Such a strategy should encompass sustainability, including both social and development goals. Hong Kong clearly needs to redefine the importance of water, which is still perceived as an abundant resource by the community at large. Hong Kong's long-term water sustainability should then be given a higher policy priority. Effective governance of the water sector, as one integrated policy area, needs substantial reform, not improvements at the margin.

In terms of management, the government should, in parallel, clarify the multiple and seemingly overlapping responsibilities across numerous departments on different aspects of water supply, including safety, quality and disposal, while moving towards an integrated approach. The various departments should strive to introduce incentives for staff for proactivity and creativity, and promote transparency within both the private sector and the government itself.

Until water security is explicitly considered in policy and relevant departments held to account, Hong Kong will continue to struggle to manage its water sustainably.

Plug Gaps in the System

Tackling leakage and losses throughout the entire water supply network must be a core component of any strategy for bolstering Hong Kong's long-term water security. A third of our valuable freshwater should not be, literally, slipping through the cracks. Accordingly, a combination of strengthening the prosecutorial powers of the WSD, expansion of repair and maintenance efforts, and enhanced monitoring should all help to address this multi-faceted issue.

Diversifying Water Supply

In addition to conservation, Hong Kong must also explore and expand local water sources to diversify and optimise supply.

In seeking to develop a future water management system that offers resilience and sustainability, Hong Kong should consider moving towards a circular water system. This means maximising the reclamation, treatment and reuse of the one billion m^3 of wastewater generated each year. In addition to significantly developing such local capacity, decentralised and district-wide rainwater harvesting should be expanded.

Desalination has been persistently championed by the government and a facility is scheduled for construction at Tseung Kwan O, commencing in 2018. This is despite ongoing concerns of LegCo members about the costs and the benefits. Before this HK$9.3 billion project begins, more than HK$118 million will have been spent, over just five years, on consultants, design and planning works. Combined with the plant's promise of meeting just 5% of daily demand with its first phase and operating only during drought conditions, the facility at Tseung Kwan O as it stands, is at risk of being an expensive project with little overall impact on Hong Kong's long-term water security.

Another long-term consideration, which remains costly and potentially divisive, is the deepening or expansion of Hong Kong reservoirs, thereby increasing local storage capacity. The WSD has considered these options, particularly for small and medium-sized reservoirs subject to more frequent overflows from heavy rain. However, these strategies have long been considered prohibitively expensive, technically challenging, environmentally unfriendly and ultimately "undesirable."

Go Smart and Encourage Innovation

For Hong Kong to move towards becoming a smart city, the WSD should be encouraged to embrace new technologies, as well as learn from and employ best practices from around the world. The department has been stagnant for too long, overly cautious, and often held to account by LegCo. Smart metering, smartphone applications and the home-grown 'Water Intelligent Network' have all passed

through varying stages of trial and assessment. Hong Kong can no longer afford to dedicate decades and hundreds of millions of dollars to insufficient and protracted research, which is in danger of delivering expensive, cumbersome and rapidly outmoded products.

To promote conservation and enhance both demand- and supply-side management, the WSD also needs to accelerate its switch to smart meters. Such a move could markedly improve public awareness, potentially encourage better engagement with the WSD and the broader government on water issues, as well as encourage heavy users to either defend their demand or reform. In the era of big data, transparency is key. Relevant data generated or collected should be publicly released.

Embark on Stakeholder Engagement with Consumers

The WSD must consider embarking on a comprehensive public engagement programme to raise the awareness of its consumers on water conservation and issues of public concern. There have been water conservation programmes, but their effectiveness is in doubt as the water use per capita in Hong Kong is still high and knowledge of water stress appears largely absent. The current rhetoric around water resources as "precious" is insufficient and has not been reinforced by actions demonstrating the value of water or the severity of Hong Kong's situation. The potential threats to Hong Kong's supply must be highlighted and government initiatives addressing them must be promoted. Targets should be set to facilitate water conservation accompanied by robust mechanisms for measuring and reviewing progress.

Implement Much-Needed and Long-Awaited Tariff Reform

Raising tariffs strategically, and so that they do not harm the poorer members of society, would allow the WSD to recoup a greater share of its operational overheads and, at best, would promote water conservation. For Hong Kong residents living below the poverty line, however, it is imperative that access to clean water is not compromised. There is, nevertheless, scope for those who earn more to pay more, without disadvantaging those with lower incomes.

Act with Urgency

On many environmental and sustainability issues, Hong Kong lags behind neighbouring cities and, more broadly, those of China. Water supply and management issues have been inadequately addressed for over two decades despite outstanding recommendations from the government's own Audit Commission (AC). As cities throughout the PRD respond quickly to urban and environmental change, Hong Kong must also respond with the same sense of urgency.

Prioritising the Options

For Hong Kong to ensure a water secure future, it must clearly continue to address non-revenue water challenges and develop water management strategies in harmony with the PRD. Naturally, the optimal strategy must balance and prioritise alternatives based on cost, environmental impact, feasibility and volume of water saved or produced, as well as public concerns.

Under its TWM Strategy, the WSD has pledged to expand and diversify local taps and significantly improve conservation. The combination of approaches identified in the TWM Strategy aims to save 236 million m^3 of water per year by 2030.

Informed by the findings of this report, an alternate approach that illustrates the inadequacy of the TWM Strategy is highlighted, focusing on addressing areas where government performance has been lacklustre and where renewed action could result in significant water savings. Measures are suggested which, if realised by 2030, would potentially save a volume equivalent to 24% of Hong Kong's projected annual freshwater demand, more than doubling the savings proposed by the TWM Strategy. In doing so, it is estimated that the Dongjiang's contribution to Hong Kong's freshwater supply could be reduced from the 60-80% at present, to 40-60% by 2030.

However, this remains a purely academic exercise. Without strategic debate of some of the key issues raised in this report, including identification of social goals and values of water resource management to inform a sustainable water strategy; adoption of a new approach will remain out of reach.

1 INTRODUCTION

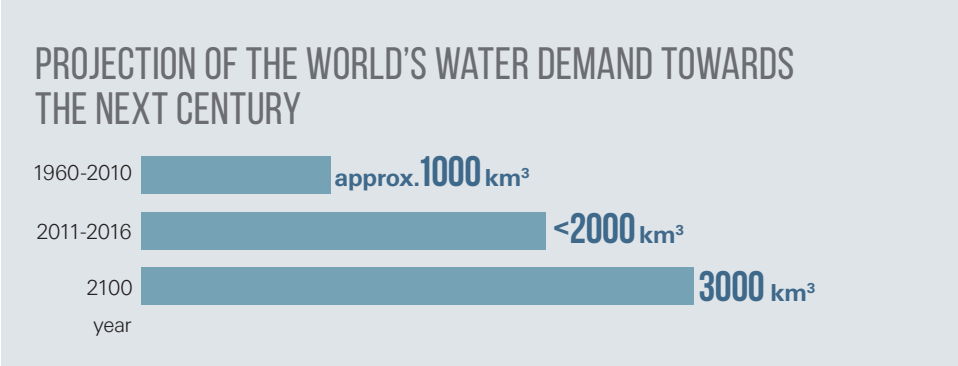
1.1 Global Water Stress

Freshwater is fundamental to life on Earth. Not only do we need water to live, we need it to produce food and energy. Only about two percent of the world's water is freshwater, the remainder is saline or brackish. At the macro level, climate change and the resulting proliferation of extreme hydrological events are adversely impacting our freshwater resources. Locally, anthropogenic activities, such as irrigation, reservoir development, urbanisation, deforestation and poor water management are contributing to rising temperatures and aggravating the pressures on water throughout Earth's natural systems.

Water resources are under increasing stress as global population and consumption increases

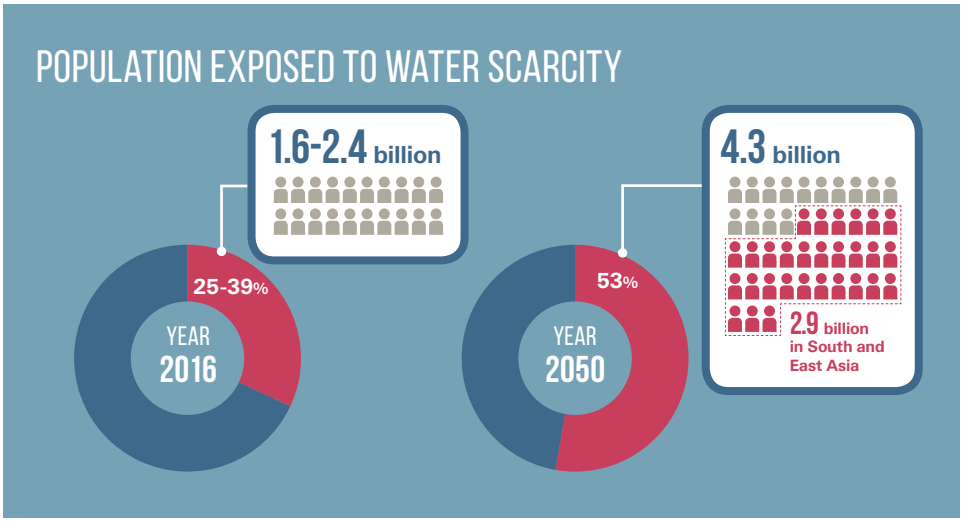
A growing population is putting water under more stress. It is projected that the world's population will reach 7.71 billion by 2020, 8.42 billion by 2030, 9.04 billion by 2040 and 9.55 billion by 2050.[1] Today, the global population consumes more than two-thousand cubic kilometres* of water per year – a thirst that more than doubled from the 1960s to 2010s.[2] During those 50 years, water consumption for food production doubled from 650 to 1,400 km^3 per year, as industrial and domestic demands respectively tripled and quadrupled. By the end of the century, global consumption is projected to increase by an additional 50%, to 3,000 km^3 per year. The intensity of consumption will be especially striking in Africa, Asia and South America, as these continents continue to develop. Household water requirements are expected to more than double from their current consumption rates, while industrial and agricultural demands follow more slowly.

* $1m^3 = 1{,}000$ litres; 1 billion $m^3 = 1km^3$



Climate change and rising global temperatures are set to exacerbate water scarcity

Already, it is estimated that between 1.6 and 2.4 billion individuals (25-39% of the population) live within watersheds already exposed to water scarcity.[3] By 2050, as many as 4.3 billion people (53% of humanity) could face water scarcity, with up to 2.9 billion located in South and East Asia.[4] The Intergovernmental Panel on Climate Change (IPCC) indicated, in its Fifth Assessment Report, that for every 1°C increase in global temperature, a further 7% of the Earth's population would face decreases in freshwater availability.[5]



China, like many countries, is already battling water crises as the nation strives to provide sufficient water for agriculture, industry and a growing population. Two-thirds of China's 669 cities face some form of water shortages[6] and the 2015 official State of Environment Report has China's overall environmental quality worsening. More than 140 million Chinese citizens have been affected by water contamination[7] and 78.3% of lakes are plagued by eutrophication[8]. Furthermore, an estimated 52 million rural citizens still lack access to safe drinking water at the end of 2015[9]. As for the PRD, the 2015 Guangdong Water Resources Report classified 39% of the PRD and 17% of the Dongjiang River as "unsafe for human contact."[10]

1.2 Pressure Mounting in the Pearl River Delta

Hong Kong lies within the Pearl River Delta (PRD), part of the third-largest catchment in China based on drainage area.[11] Economic activity within the delta has been a major driver of development in Guangdong.[12] The province contributes 10% of China's GDP. One of the most significant tributaries of the Pearl River is the Dongjiang (Dong, or "East" River), which flows 562 km from Jiangxi Province through eastern Guangdong Province, terminating in the PRD (Figure 1).

FIGURE 1

Hong Kong and fast growing urban centres in the PRD rely on the Dongjiang for the majority of their freshwater

Hong Kong and seven major urban centres in the PRD rely on the Dongjiang for freshwater. Four of these depend on the river for between 70% and 90%[13] of supply. Hong Kong is the furthest city downstream of the Dongjiang and relies on the river for up to 80% of its freshwater.

Overall, there are more than 20,000 water pumping-diversion projects located in the PRD catchment[14], which sustains 40 million people including Hong Kong's population of more than 7 million[15]. Although Guangdong has allocated water resources to Hong Kong, meeting the city's need to supplement its reservoir water since the 1960s, Hong Kong should not assume that will always be the case.

In 2008, the eight major cities (including Hong Kong) consumed double their allocated water volumes

A key concern is the vulnerability of major cities in the PRD, including Hong Kong, to changing regional environmental conditions. In 2004, the total withdrawal of water from the Dongjiang surged past the assumed ecologically safe level of 10.66 billion m^3, equivalent to 33% of the river's annual average discharge[16,17]. Two years later, in 2006, Guangdong's provincial authority capped Hong Kong's allowable allocation at 820 million m^3.[18] In 2008, the eight major cities depending on the Dongjiang (including Hong Kong) consumed double their combined allocation (21.2 billion m^3).[19] That year, Guangzhou exceeded its annual allocation six-fold. The Chinese government capped total water use in Guangdong at 45.7 billion m^3 in 2015, and is aiming to lower this to 45.6 billion m^3 by 2020, and 45 billion m^3 by 2030.

A catchment-wide shortfall would have severe consequences for the entire PRD. The ability to withdraw water is fundamentally limited by the capacity of the Dongjiang which, in turn, is reliant on rainfall across its 27,040 km^2 catchment, a basin heavily influenced by the sub-tropical monsoon. Under changing atmospheric and oceanic conditions, rainfall distribution, frequency, seasonality and volume are all shifting.[20]

1.3 Hong Kong, under an Illusion of Plenty

Despite Hong Kong having less water than parts of the Middle East and Africa, there exists an unfounded *illusion of plenty*

Hong Kong is in fact naturally water-scarce, having less water per capita than parts of the Middle East and Africa.[21] It is devoid of major rivers, lakes, or even notable groundwater stores, and yet supports a population of 7.3 million, densely packed into its limited landmass, amounting to over 6,600 people per km^2 [22]. However, the yield from typhoons and heavy rainstorms throughout much of the year, heavily augmented by a steady supply of high quality, potable water from China, provide Hong Kong with a seemingly boundless supply that has left the majority of Hong Kong's residents unaware. The apparent abundance of water has created an *illusion of plenty*, which in turn has bred complacency, wastefulness and unsustainable demand.

Despite a relatively high average (2,300 mm) yet variable (900-3,300 mm) annual rainfall between 1961 and 2015, Hong Kong's local yield has been insufficient to satisfy local demand for almost half a century.

Since the 19th century, Hong Kong, like its neighbour Singapore, has faced the threat of water scarcity. In World War II, the invading Japanese army forced the quick surrender of both colonies by cutting off their water supplies. Yet, while Singapore's leader Lee Kwan Yew pushed the world's last remaining island city-state toward water self-sufficiency over the next fifty years, Hong Kong faltered.

Hong Kong started importing water from Guangdong in the 1960s and its efforts to achieve self-sufficiency were largely abandoned in the late 1970s, as the dynamics between China and Hong Kong changed. Since that time, Singapore has leapt ahead, nearing self-sufficiency. Meanwhile, Hong Kong has fallen behind, now relying heavily on resources from China.

While Hong Kong's government historically sought to secure a constant, clean supply of freshwater on the population's behalf, today water security has largely disappeared from the political arena, and thus the public eye. Yet, a thirsty and growing PRD population, water-intensive industries and climate change all increasingly threaten to disrupt the supply. Notably, China, facing an uphill battle to manage its own water resources, has introduced water reform policies that put Hong Kong's few token efforts over the past two decades to shame.

WATER SECURITY is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.

Source: UN-Water, 2013

As part of the PRD, Hong Kong has a responsibility to manage its water demand and inflowing water supply effectively

As part of the PRD, Hong Kong cannot consider itself in isolation. What happens in the PRD has consequences for Hong Kong, and vice versa. Hong Kong has a duty to manage its demand and the inflowing water supply effectively. The government has the opportunity, and a socio-economic and environmental responsibility to lead Hong Kong towards a future in which the PRD's water supply is secure.

This report presents the results of numerous interviews and an extensive review of documents, articles and reports spanning more than two decades, seeking to identify and elucidate the key challenges that continue to threaten Hong Kong's long-term water security. It brings together the latest information and highlights key areas for Hong Kong to address in moving towards greater water security in the PRD, as follows:

Hong Kong's Water Landscape sets the scene, highlighting the realities that dictate how Hong Kong satisfies its thirsty populace.

Defining the Challenges explores the realities, including the threats to supply, the role of climate change, overconsumption, the inadequacies of governance, the local water tariff system, regional and local demands and the lacklustre performance of relevant government departments over two decades.

Striving Towards a Water Secure Future lays out a variety of recommendations and considerations to address the identified threats and challenges to Hong Kong's water security, both for the short- and long-term.

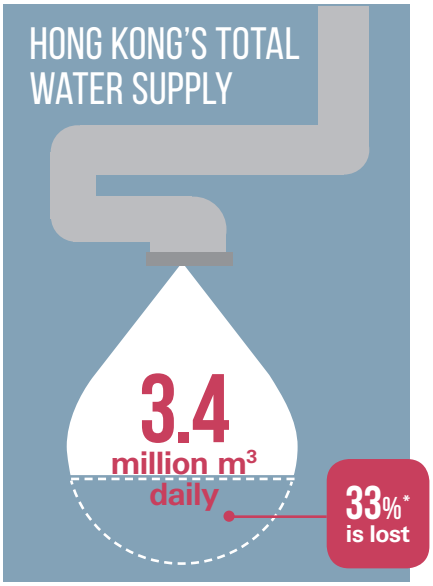
Balancing Options at a Glance presents alternative water saving options to the government's Total Water Management Strategy.

2 HONG KONG'S WATER LANDSCAPE

2.1 Water Resources and Supply – insufficient resources

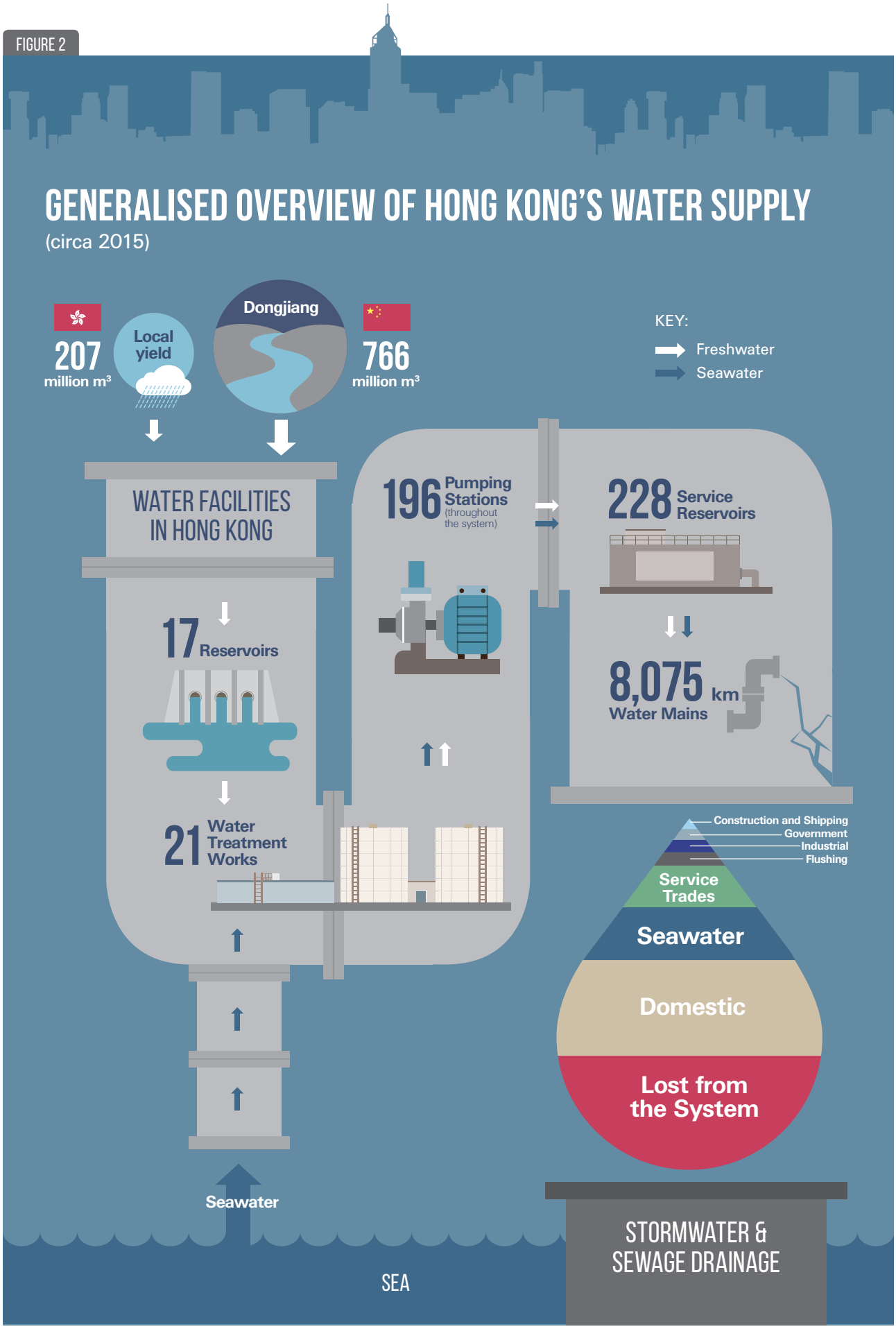
Public water supply services in Hong Kong date back to 1851[23], when four government-funded wells were sunk in Central to provide water for the population on Hong Kong Island. With Hong Kong's natural water resources being limited to a network of relatively small rivers and streams,[24] the 1960s and 1970s saw the construction of two large reservoirs: Plover Cove and High Island. Engineers walled off the adjacent sea, drained the seawater and replaced it with rainwater collected from the surrounding country park catchments. Today, around one-third of Hong Kong's total land area has been designated as water gathering grounds[25].

Despite heavy seasonal rainfall, Hong Kong's capacity to harvest precipitation is, on average, around 30,000 litres per capita per year. This means that every Hong Kong resident has access to 84 litres of locally-sourced freshwater each day. This contrasts with the local daily total freshwater consumption, which amount to approximately 132 litres per capita per day[26], 50% more than the local system can provide. Unlike China,



*as of 2015

FIGURE 2



Note: Sea and freshwater flow through seperate distribution systems

Hong Kong's groundwater reserves are largely not considered as a viable freshwater source, furthermore research indicates extensive contamination which has further consequences for local water quality in rivers and regional seas[27].

Today, in order to meet the growing demand[28], extensive infrastructure across Hong Kong distributes 3.4 million m^3 of water daily (Figure 2).[29] Nevertheless, local resources provide about one-quarter of freshwater supply. Unfortunately, approximately one-third of the water supplied is lost (see Section 3.3.1). The local network is plagued by aging infrastructure, a somewhat reactive approach to maintenance further complicated by illegal diversions and leakage of valuable water.

2.2 Water Demand and Use – Demand Rising

In 2015, Hong Kong's freshwater consumption was 21% higher than the global average, at 132 litres per day

In 2015, Hong Kong consumed a total of 1.25 billion m^3 of water (both sea and freshwater), equivalent to 171,000 litres (171 m^3) per capita (Figure 3) or nearly 860 full bathtubs per person.[30] Over half of freshwater actually consumed was for domestic use. A quarter was utilised by service trades (e.g. catering, hotel sector), and the remainder was employed by industry, construction and shipping, in government establishments, and used as flushing water.

Since 1989, total freshwater consumption has risen steadily, largely as a result of increasing domestic consumption and, by 2015, it had reached 973 million m^3, an increase of 15.1%.[31]

Domestic Use – The Lion's Share

In 2015, the Water Supplies Department (WSD) reported per capita domestic consumption was around 132 litres per day[32], 21% higher than the global average of 110 litres[33]. If the domestic consumption of seawater used for flushing is factored in, this figure rises to 224 litres per day[34].

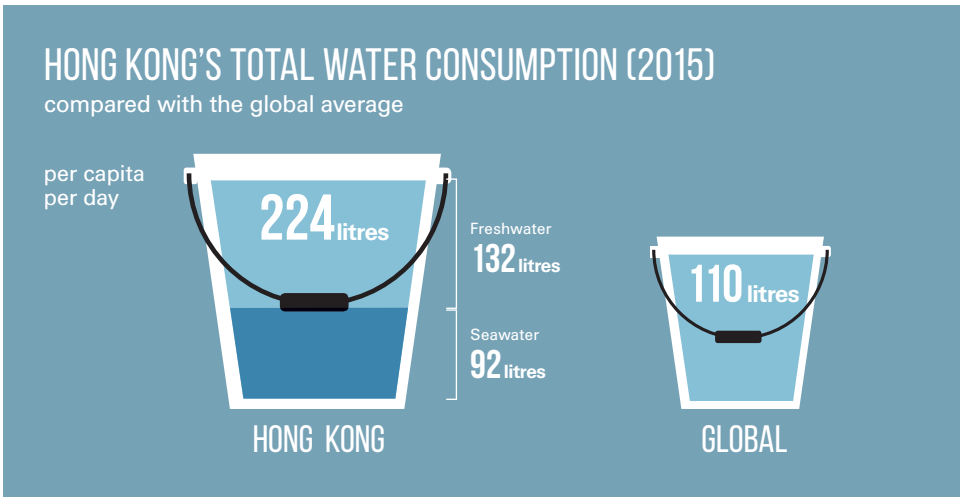


FIGURE 3

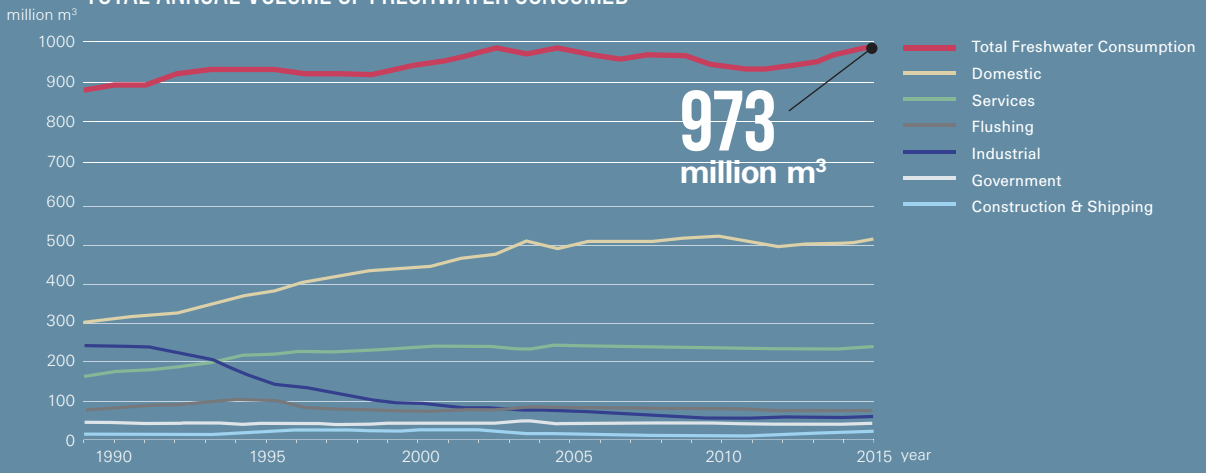
HONG KONG'S WATER USE

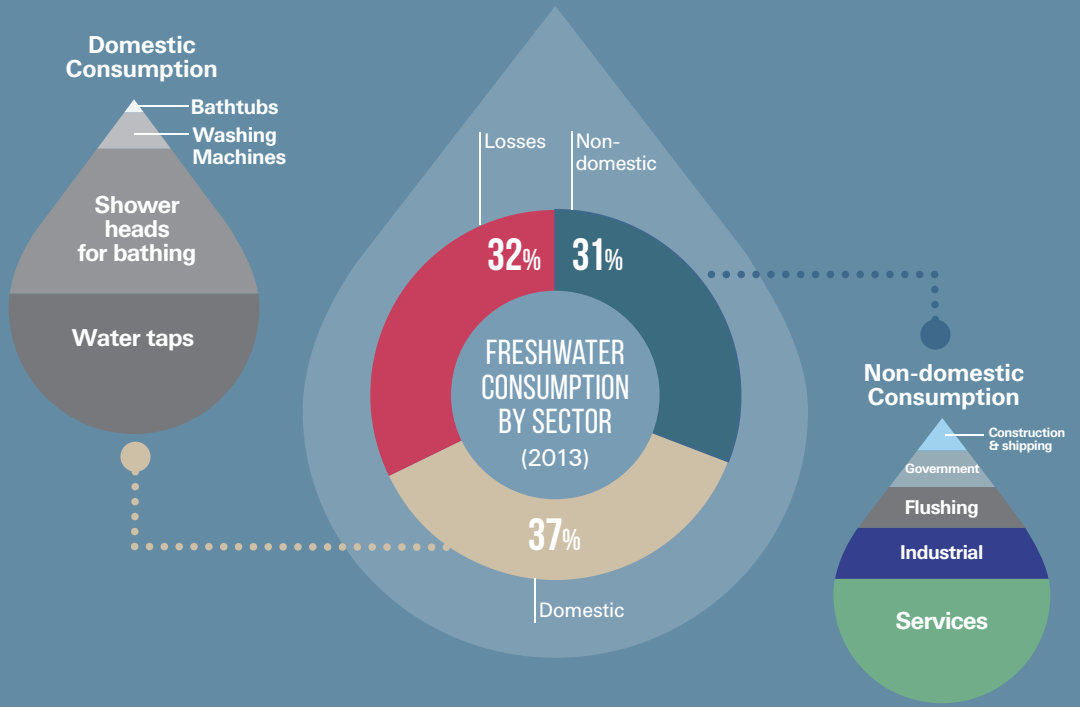
HONG KONG'S TOTAL WATER CONSUMPTION* (2015)

*seawater and freshwater

1.25 billion m³ = **860 full bathtubs per capita**

TOTAL ANNUAL VOLUME OF FRESHWATER CONSUMED





Hong Kong is unique[35], as 80% of the local demand for flushing water is satisfied by seawater[36].

However, based on the WSD's data, domestic users received 526 million m^3 of freshwater in 2015.[37] Divided equally across the 7.3 million people who were supplied by the WSD that year, the average usage would therefore appear be closer to 197 litres per day. The difference of 65 litres is assumed to be water that is unaccounted for, i.e. water lost from the system (see Section 3.3).

BOX 1

2011 Domestic Water Consumption Survey – How Does Hong Kong Use Water in the Home?

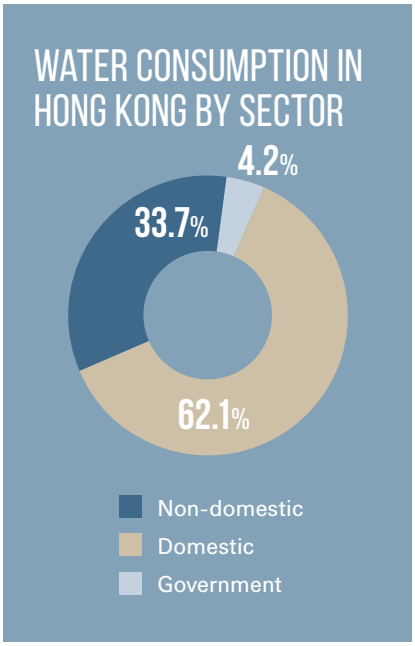
Source: UN-Water, 2013

In 2011, a survey by the government found that Hong Kong households comprising 1-2 members consumed 143 litres (0.143 m^3) per capita daily, whereas those with 3 or more used at least 20% less.

The more inhabitants per household, the lower the per capita consumption. The average household uses 124.7 litres per capita each day.

Non-domestic Use

Industries and service trades along with construction and shipping consumed a combined 303 million m^3 of freshwater in 2015.[38] It is noteworthy that Hong Kong, unlike many other major cities, does not have to use vast quantites of freshwater for power generation cooling and instead uses seawater. Yet, Hong Kong's total freshwater conumptuion is still considered to be high.



Similar to domestic use however, there is very little disaggregated information, exploring the usage within the sectors by user or type of consumption.[39] Independent studies and regional reports remain the key sources of information for these sectors and generally account for only a small sample within each segment. Annual or sustainability reports covering 'Environmental, Social and Governance' (ESG) indicators also provide some data, but they are often opaque[40].

Government Use

Consumption across government establishments has been relatively constant since the 1980s[41]. Demand has remained between 40-46 million m^3 per year, with one exception in 2003, when it was higher[42].

The Audit Commission (AC) determined that the Leisure and Cultural Services Department (LCSD), Correctional Services Department (CSD), and Food & Environmental Health Department (FEHD) have been the heaviest government consumers, based on data from 2011-2016.[43] Despite accounting for approximately half of all government consumption, these three departments do not disclose water use data and do not appear to have any publically available department-wide water reduction targets.

2.3 Local Management and Governance

The WSD is Hong Kong's leading authority on water, charged with overseeing and implementing the Waterworks Ordinance and Waterworks Regulations. In doing so, the department manages the water supply and the distribution network, including treatment plants, service reservoirs, pumping stations, and mains pipelines.[44]

It monitors the quality of the water supply, plans waterworks projects (i.e. tunnelling, reservoir construction) and oversees maintenance. It regulates plumbing works on both public and private property, and has mandates to prosecute offenders for unauthorised withdrawals from the network.

WSD's Mission

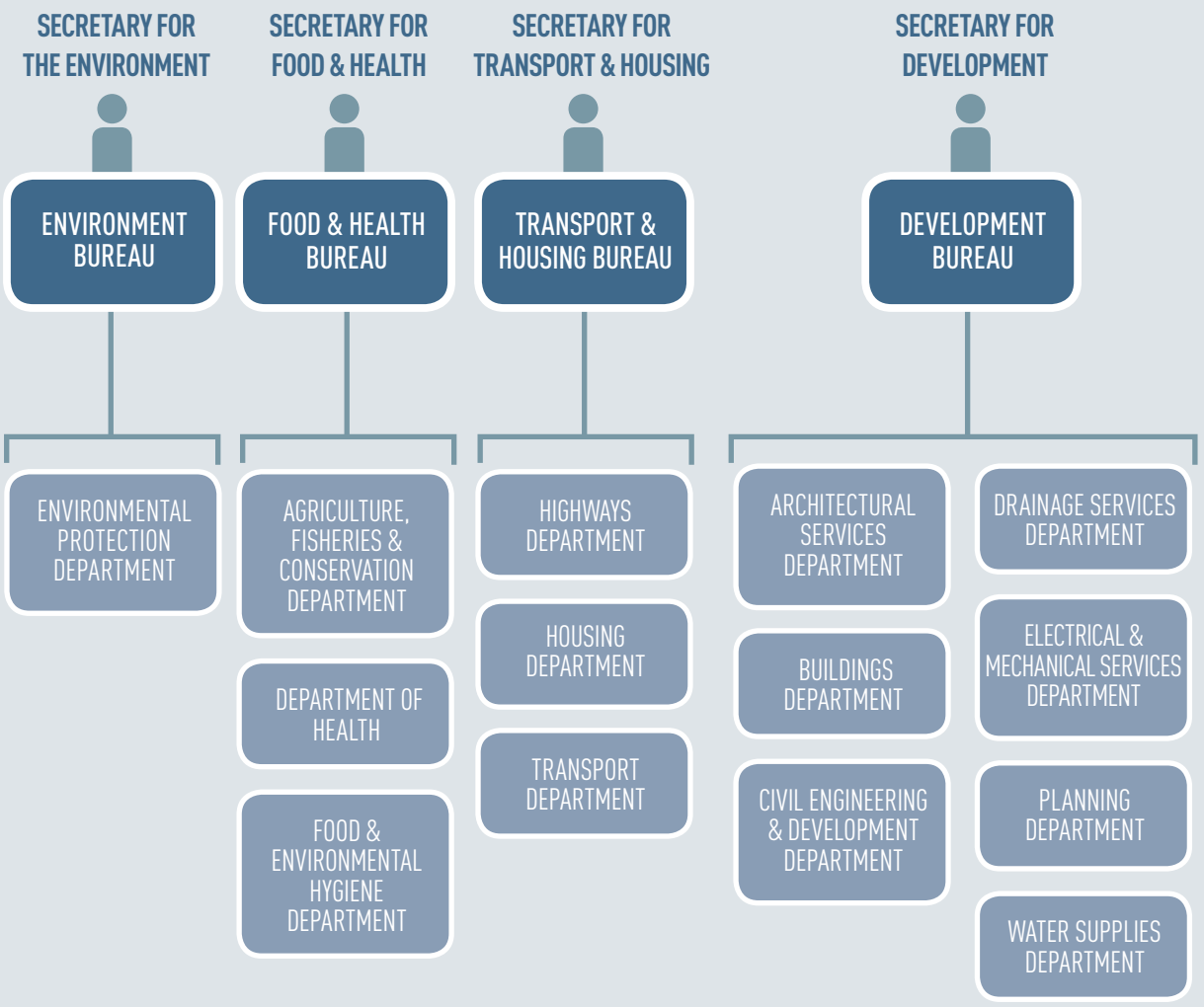
To provide a reliable and adequate supply of wholesome potable water and sea water to our customers in the most cost-effective way

Multiple government departments and bureaux are involved in monitoring, maintaining, and constructing parts of Hong Kong's water system

Due to the nature of these services, multiple other departments and their bureaux are also involved in varying aspects of monitoring, maintaining and constructing parts of the water system and related infrastructure (Figure 4). The departments that perhaps coordinate most closely with the WSD are the Drainage Services Department (DSD) and Environmental Protection Department (EPD). The DSD is responsible for managing wastewater and stormwater, ensuring that the sewerage and drainage networks remain operational.[45] It has a number of branches that oversee specific aspects of operations. The Sewage Services Branch, for instance, implements sewerage and sewage treatment projects, and receives the charges for the service.

FIGURE 4

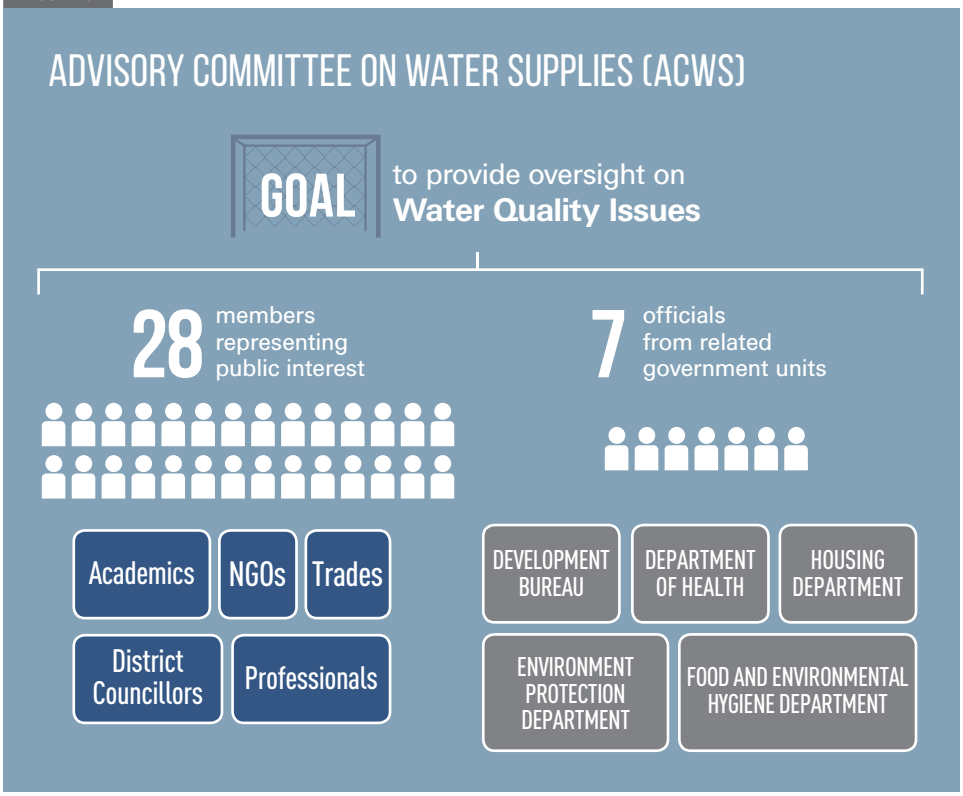
GOVERNMENT'S INVOLVEMENT IN MANAGING WATER OR RELATED INFRASTRUCTURE



The EPD is concerned with enforcing the Water Pollution Control Ordinance[46], including administering discharge licenses, and monitoring the quality of water throughout Hong Kong. It is responsible for reviewing Environmental Impact Assessments (EIAs) and providing environmental permits. The WSD and DSD are immediately subordinate to the Development Bureau (DevB), under the Secretary for Development. The Environment Bureau (ENB) oversees the EPD.

Specialist water-related projects, such as laying submarine infrastructure, construction of dams and the Tseung Kwan O desalination plant, are often outsourced to a small network of global consulting firms. Certain tasks are also overseen by independent bodies, such as the Advisory Committee on Water Supplies (ACWS) established in 2000 to provide oversight on water quality issues (Figure 5). In 2012, its remit expanded to cover the supply network and by 2016 its concerns grew to include water network management. The ACWS currently aims to provide transparency on key water issues and strives to involve the public in water quality monitoring and network management.[47]

FIGURE 5



3 HONG KONG'S WATER SECURITY CHALLENGES

3.1 Reliance on the Pearl River Delta

3.1.1 Competing Demands on Water Resources

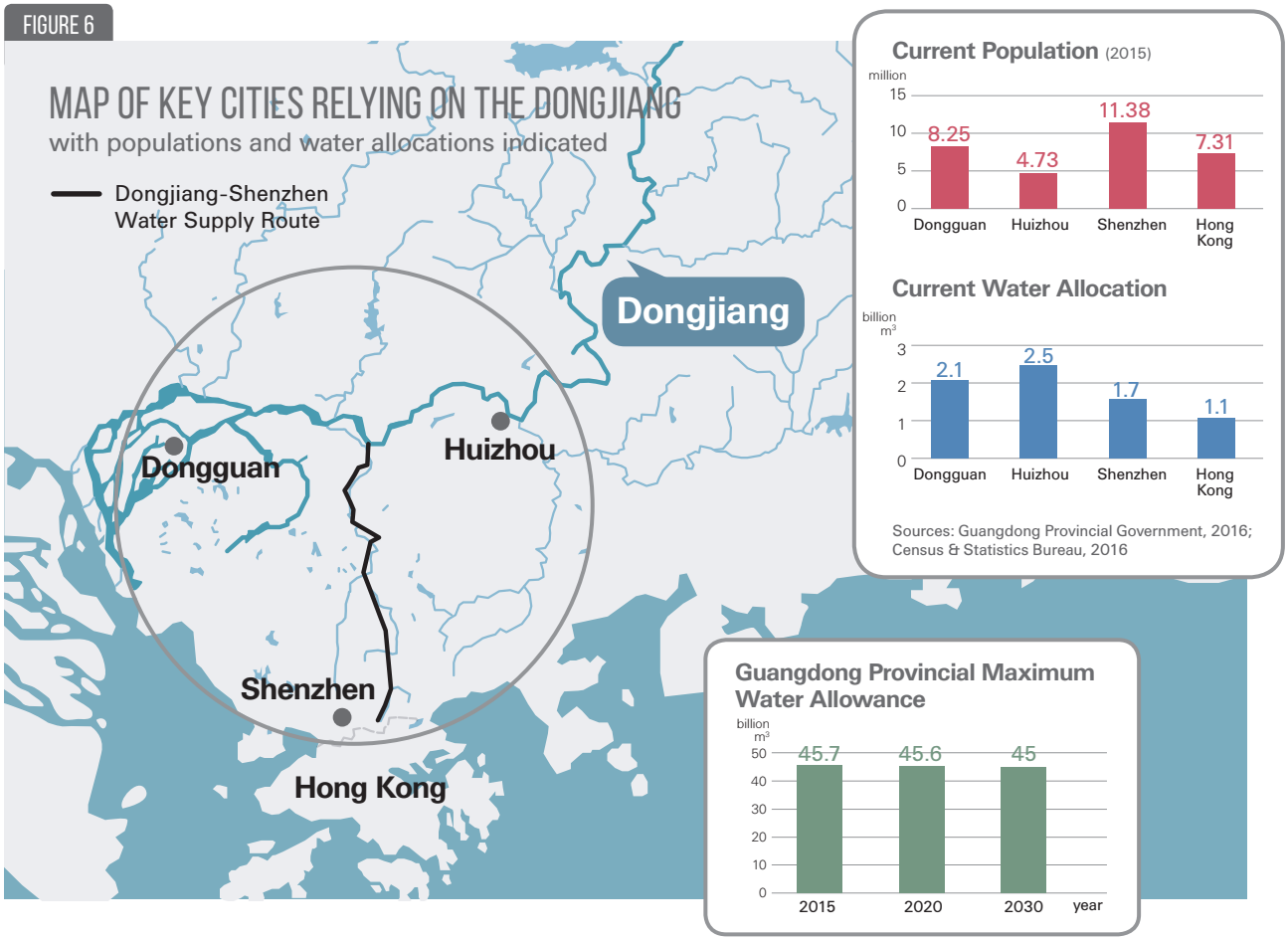
Despite concerns over competing demands for water, recent research indicates that strict enforcement of water regulations in the PRD has triggered "significant improvements in industrial water use intensities, and early stabilisation of domestic water use intensities[48]." It appears that total water consumption in the PRD has returned to 2002 levels, with Shenzhen achieving especially impressive reductions in water intensity.

The policies enacted and enforced by the authorities in Guangdong are largely considered to be responsible for this.[49] Improving irrigation methods and having a stricter oversight of industrial consumers' demands, whereby heavy users are forced to reduce or leave the province, are likely the key drivers behind the decreasing water intensity.

By 2020, Huizhou, Dongguan and Shenzhen are expected to exceed their water allocations by 18%, 20% and 56%, respectivley

However, both industry and the regional population have experienced significant growth (Figure 6).[50] Water Affairs Bureaux in Huizhou, Dongguan and Shenzhen have projected that, as water-hungry manufacturing expands, their respective cities will exceed their water allocations from the Dongjiang by 18%, 20% and 56% by 2020.[51] These three cities combined already withdraw almost six times as much water from the Dongjiang as Hong Kong.

FIGURE 6



3.1.2 Sufficiency of the Dongjiang Remains Uncertain

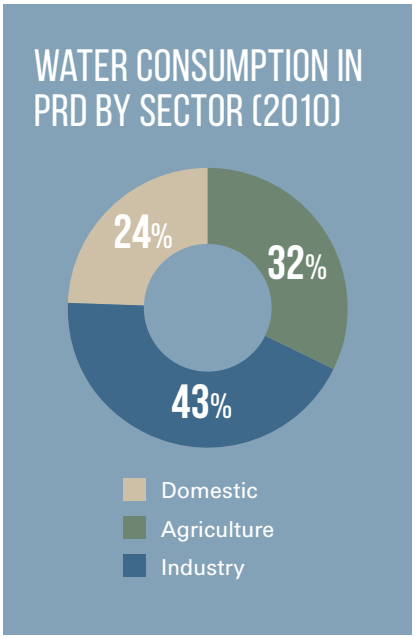
It has been reported that the annual flow of the Dongjiang has been declining since the 1950s, influenced by climate change[52], giving rise to concerns that its supply may not be sufficient for an increasingly thirsty PRD, in the future. Further, it has been projected that by 2079-2099, river flow in the Pearl River catchment could see a 24% reduction (compared with the 1979-1999 average).[53]

However, a leading expert of water resources in the PRD and Dongjiang basin has stated that there is no indication that water availability from the river is decreasing or will do so in the near future[54], though there has certainly been considerable interannual variability[55]. Importantly, the reservoirs throughout the course of the Dongjiang play a key role in modulating and augmenting water availability in the catchment.[56] The Shenzhen Reservoir has acted as a conduit and store for Dongjiang waters since 1964[57], but, the most critical facility on the river is the Xinfengjiang Reservoir.

With a capacity of 13.9 km^3 [58], the Xinfengjiang Reservoir acts as a massive stabilising force: its volume is sufficient to satisfy the demand within the Dongjiang basin for at least a year, in the event of a shortfall[59]. Despite the vast combined capacities of the Xinfengjiang, Fengshuba and Baipenzhu reservoirs, the stored volume of the Dongjang declined by 25% below normal between 2004 and 2009, as rainfall decreased by up to a third.[60] The shortfall then was severe enough that hydropower facilities throughout the basin were shut down, to ensure the demand from the cities was met.

The threat of water shortfalls is especially concerning for the agricultural sector

The threat of water shortfalls is concerning for the agricultural sector as 33% of the PRD is dedicated to cultivation. Hong Kong and Macau import more than 50% of the 11 million tonnes of vegetables grown within the delta.[61]



LegCo has indicated, "there is no assurance that [the] Dongjiang will always be able to provide a constant water supply for Hong Kong"

In 2015, LegCo's Research Office stated that, "there is no assurance that [the] Dongjiang will always be able to provide a constant water supply for Hong Kong."[62] Daiwa Securities Group Inc., a Japanese investment bank, assessed the robustness of Guangdong Investment Limited (GI) (which oversees the delivery of Dongjiang raw water to Hong Kong) in 2016, and estimated that the Dongjiang will only be able to meet 84% of demand from surrounding cities by 2020.[63] Further, the WSD estimated a future shortfall in freshwater resources amounting to 39 million m^3 per year, approximately 4% of Hong Kong's current annual freshwater supply.[64] By 2020, the WSD's projections indicate water demand will remain comparable with current demand, at approximately 970 million m^3.[65]

In a drought situation, with local reservoirs at their fullest capacity, Hong Kong could potentially maintain freshwater supplies for 31 weeks, assuming consumption remains stable.[66] Notably, Hong Kong required more than 90% of its allotment from China in six of the last fifteen years. In 2011, 818 million m^3 (99.8% of its allotment) of raw water was withdrawn from the Dongjiang.

Changes in regional water supply thus have direct consequences not only directly for Hong Kong's water security, but also potentially impact food security, industry and trade.

Hong Kong may soon have to rely on water from the Xijiang, as well as the Dongjiang

While Hong Kong has become reliant on the PRD, its supply may also soon rely on diversion of water from the Xijiang (Xi, or "West" River), as the Dongjiang starts to reach capacity. However, the Xijiang is already facing challenges of its own (Box 2). Nevertheless, both the Dongjiang and Xijiang are unlikely to be compromised by drought at the same time. The rivers are fed by two very different catchments, with their own discrete climatic regimes[67]. Further, the Xijiang is fed by groundwater and precipitation across its 350,000 km^2 catchment, which is thirteen times the size of the Dongjiang catchment.

BOX 2

The Xijiang - Tarnishing the 'Golden Waterway'

Sources: Lau, 2012; People's Government of Guangzhou Municipality, 2016; Wu et al., 2015; Mo, 2011

To meet increasing demands, the Guangdong government announced that it would spend HK$31.6 billion (RMB 25 billion) to ensure Shenzhen's growing water needs are met, with 700 million m^3 being diverted from the larger Xijiang. Withdrawals were to be transferred via a 95-kilometre aqueduct, ensuring the supply to Dongguan and Shenzhen. By 2016, Guangzhou had already invested approximately HK$10 billion (RMB 8.24 billion) in diverting 3.5 million m^3 of raw Xijiang water every day.

Over the next decade, the Xijiang is likely to augment ever more the Dongjiang's supply. However, Xijiang – the so-called 'Golden Waterway' – is already under pressure because of drought, largely from changing atmospheric conditions. In December 2011, for instance, 900 shipping vessels were stranded in Wuzhou, in the Guangxi Zhuang Autonomous Region, as the river runoff declined by 30%. Even without climate change, severe droughts return to the area approximately every 20 years and extreme droughts have taken place every 50 years or so.

In conclusion, it remains unclear how the balance of water resources in the region will change in the future, though climate change will undoubtedly increase the magnitude of extreme events. Ancillary impacts, such as higher pollution concentrations, may also occur during periods of drought or flooding. What is clear, however, is that water scarcity and drought are risks that, despite any scientific uncertainty, need to be recognised and rapidly tackled by Hong Kong's government as well as its public.

3.1.3 Climate Change and Water Security

Regional water availability is being compromised by the threat of warming across the Earth's surface. The Paris Agreement of 2015 aspires (but does not legally bind countries) to limit temperatures to "well below 2°C above preindustrial levels"[68] by the end of the century. Yet, a recent paper by leading international experts projects that business-as-usual could see temperatures climb to 4.8°C to 7.4°C above pre-industrial levels[69].

Scientists have indicated that in order to avoid the most catastrophic consequences, it is imperative to rapidly reduce carbon dioxide (CO_2) concentration to below 350 parts per million (ppm).[70] As of January 2017, concentrations of the greenhouse gas (GHG) CO_2 exceeded 405 ppm.[71] The last time CO_2 concentrations reached a comparable level – 415 ppm around 4.5 million years ago – global average temperatures were 3-4°C higher than today.[72]

The South China region has experienced a rate of warming over 120% that of the global average, since 1961

The South China region has experienced a temperature increase of 0.16°C every decade since 1961, a rate of warming over 120% that of the global average[73]. Cities, in particular, have heated at an elevated rate. A study in 2004 determined that the 'Urban Heat Island effect' has added 0.05°C to warming trends across China's urban landscapes.[74]

This trend is expected to increase throughout the remainder of the century. Similarly, research led by the Guangzhou Meteorological Survey projects that Guangdong will likely see annual average temperatures exceed the 1961-1990 norm by 3.0°C by the final decade of the century, even under optimistic circumstances[75].

Precipitation in the centre of the Dongjiang catchment amounts to approximately 1,930 mm per year, peaking between spring (March) and summer (August). Eighty percent of the annual rainfall occurs during this period. This is above average for South China, which typically experiences annual precipitation of around 1,200 mm, and considerably more than the water-starved north, which receives less than 330 mm per year.

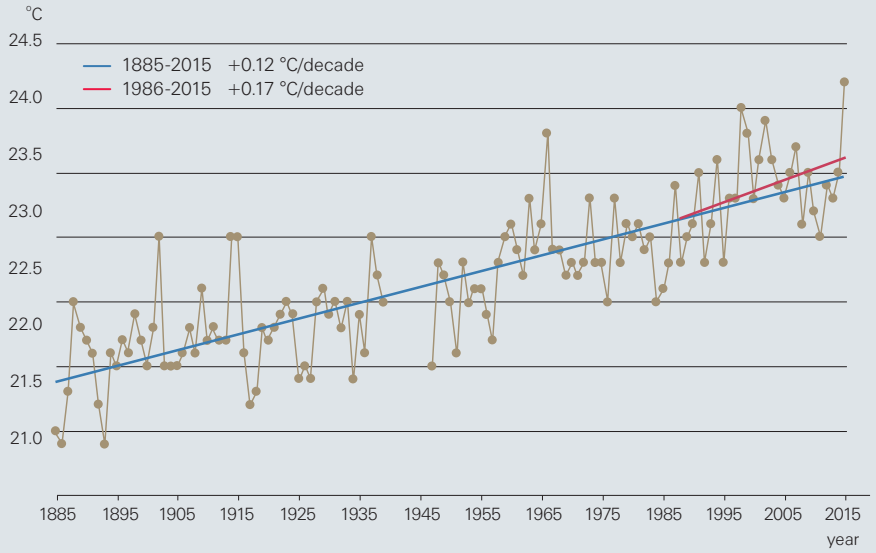
Further, trends in rainfall indicate increased availability within Hong Kong's catchments. Collaborative research between the City University of Hong Kong (CityU) and the Hong Kong Observatory (HKO) indicates that local rainfall (excluding that from typhoons) intensified between 1961 and 2012.[76] The return period of the most extreme rainfall events has also shortened. This means that maximum daily rainfall (exceeding 350 mm) from non-typhoon downpours will potentially occur once every 13 years, instead of once every 28 years, as in the 1960s.[77] However, it remains uncertain how local temperature trends may influence rainfall patterns.

Hong Kong's mean temperatures may rise by 7.36°C above pre-industrial levels by 2100

Since records began in 1885, local annual mean temperature in Hong Kong has risen at 0.12°C per decade[78] amounting to an increase of 1.56°C over a 130-year period. According to researchers at the HKO, if GHG emissions are capped before 2020 in tandem with other significant steps, temperature increases could be limited to 1.4°C by the end of the century[79,80].

ANNUAL MEAN TEMPERATURE RECORDED AT THE HONG KONG OBSERVATORY HEADQUARTERS (1885-2015)

Source: Hong Kong in a Warming World, Hong Kong Observatory 2016



Note: Data are not available from 1940 to 1946

These apparently pessimistic scenarios and the consequent impacts on water availability will likely become reality unless unprecedented progress is made to curb GHG emissions and population growth, and encourage sustainable development at local, national and global scales.[81]

3.1.4 Supplying Water from Guangdong, Shortcomings of the Agreement

Since May 1982, Hong Kong has not needed to ration its water because of the constant water supply from China

The earliest form of the current agreement to direct water from China to Hong Kong – the 'Dongjiang-Shenzhen Water Supply Project' (DongShen Agreement) – came into effect in 1965 (Box 3).[82] Water from the Dongjiang then started to flow to Hong Kong, having been redirected from the river's main course, 83 km north of Shenzhen.

The annual supply originally agreed upon in 1964 amounted to 68 million m^3.[83] However, the supply increased considerably through the successive negotiations of the DongShen Agreement. By 2015, Hong Kong imported more than eleven times the volume it received in the 1960s (Chart 1). The supply from China first exceeded local yield in the mid-1980s and Hong Kong has avoided rationing its water since May 1982[84] due in large part to the constancy of the supply from the Dongjiang. However, local demand has risen rapidly.

BOX 3

The DongShen Agreement, Who is Responsible?

Source: Ip and Lai, 2016; Guangdong Investment Limited, 2000; 2016; Tang, 2002; Financial Times, 2016

The DongShen Agreement was enacted, under the direction of the Department of Water Resources (DWR), through the Guangdong Yue Gang Water Supply Company Limited (WaterCo).

WaterCo is a subsidiary of Hong Kong-listed, Guangdong Investment Limited (GI), in which the Guangdong Provincial Government has a 54.6% equity interest, through Guangdong Holdings Limited (GDH). A further 20.9% of shares are held by institutional investors, including BlackRock and Investec. Public shareholders make up the remaining 24.5%.

WaterCo commenced operation on 18 August 2000, and immediately entered into the 'Water Project Transfer Contract' – the DongShen Agreement. The contract signed between the newly established company and the Guangdong government, permitted the company to withdraw 2.42 billion m^3 of water from the Dongjiang each year. Of this, Hong Kong received approximately 31% in 2015/16. WaterCo has the exclusive rights to supply Hong Kong, and non-exclusive rights to supply Shenzhen and Dongguan for a period of 30 years.

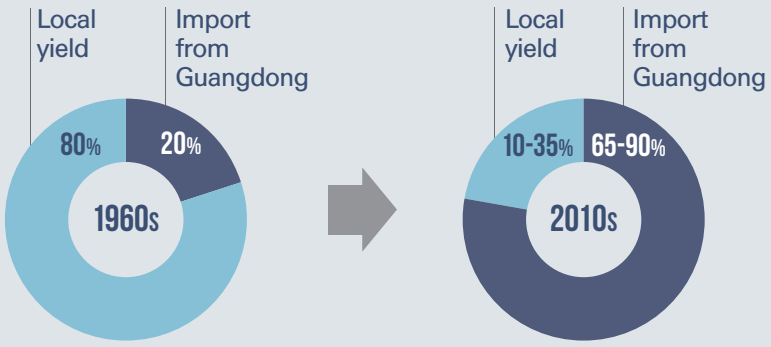
GI is led by a board of fifteen directors comprising eight Hong Kong business tycoons and former politicians. Three local directors have been members of LegCo, and two have held key positions as Executive Councillors (ExCo), advising the Chief Executive in policy and administration.

The value of the DongShen Agreement was speculated to be approximately HK$17.07 billion (US$2.2 billion), according to an article by GI's former legal counsel. The company derived nearly 46% of its annual revenue from supplying Hong Kong with Dongjiang raw water in 2015.

CHART 1

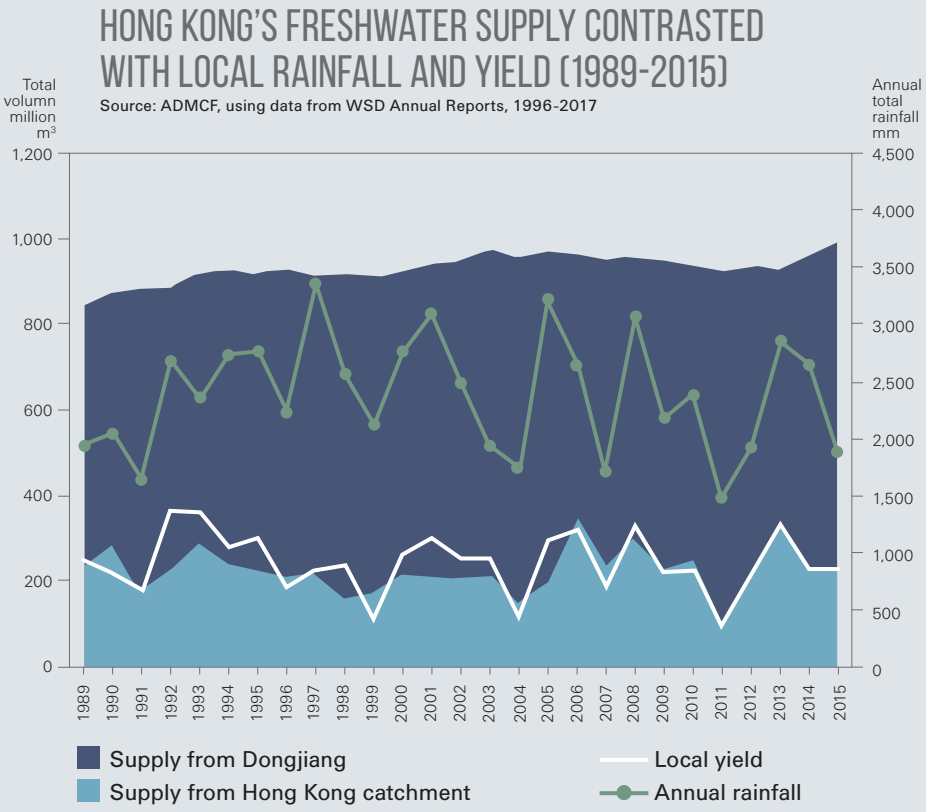
CHANGE IN PROPORTION OF HONG KONG'S FRESHWATER SUPPLIED BY DONGJIANG AND LOCAL YIELD BETWEEN 1960S AND 2010S

Source: WSD Annual Reports, spanning 2013-2015; Liu and Williams, 2014



In 1998, the three-year 'DongShen Renovation Project' was initiated, to enhance the supply network which diverts water from the Dongjiang to the south.[85] The renovation cost RMB 4.7 billion, with the Hong Kong government contributing HK$2.36 billion (half of the project expense), as part of an interest-free loan to GI, with repayments to Hong Kong in the form of advance payments for its water fees over 20 years.

CHART 2



Local yield has fluctuated by up to 69% year-to-year.[86] Overall, throughout the past twenty years, yield across Hong Kong's 17 reservoirs has oscillated between 103 million and 364 million m^3 (Chart 2), leaving stores sufficient to meet the demand of current freshwater consumption by as little as 11%, or as much as 38%. To make up for the deficits and unpredictability, 60-80% of Hong Kong's annual freshwater demand is met by the Dongjiang.

The DongShen Agreement, which is not publically available[87], is renewed every three years and under the latest iteration in May 2015, Guangdong Province committed to providing a maximum of 820 million m^3 of raw water to Hong Kong annually.

Hong Kong also retains the option to raise the annual supply ceiling to 1.1 billion m^3.[88] The WSD's projections indicate the maximum Dongjiang supply will be sufficient to meet demand for at least the next 15 years.[89]

Shortcomings of the Dongjiang agreement that led to water wastage were highlighted as early as 1999

As early as 1999, Hong Kong's AC highlighted the shortcomings of what was then a 'take-or-pay' scheme. Under the scheme, Hong Kong was obliged to take the full allocation of water contractually agreed upon, regardless of how full its reservoirs were. During the wet season it often resulted in Hong Kong's reservoirs exceeding their capacity, resulting in overflow that ultimately washed into the ocean.[90] At the time, the AC encouraged negotiators to "incorporate flexibility" into the agreement.[91] However, according to AC reports, Guangdong authorities were unwilling to reduce the supplied quantity.

Hong Kong must pay for all the agreed allocation of water from China, regardless of how much it uses, thus discouraging conservation

The Guangdong authorities would not consider any revision to the scheme in any of the intervening negotiations until 2006, when "seasonal fluctuations in the local yield" were taken into consideration, minimising overflow from reservoirs[92]. This is known as the 'Package Deal Lump Sum' approach and remains in place today[93]. Although, under this approach Hong Kong has the option of taking what water it needs, it must still pay for the entire agreed allocation, regardless of how much it actually imports (Chart 3). This mechanism discourages conservation, particularly whilst annual withdrawals have remained under the 820 million m^3 ceiling. This has further been exacerbated by the agreement to provide an absolute maximum of 1.1 billion m^3 per annum[94] – a volume 34% higher than the present supply – even during periods of drought.

Guangdong negotiators are reluctant to settle on a 'payment on actual supply quantity' approach for Hong Kong's water supply

In 2014, when Hong Kong's Legislative Councillors reportedly requested a "payment on actual supply quantity" approach[95], Guangdong negotiators made it clear that this would result in Dongjiang waters being allocated elsewhere. They stated they would not be able to ensure 99% of Hong Kong's supply, due to "keen competition." Hong Kong's DevB stated that Hong Kong would "not import [Dongjiang] water more than necessary, thereby avoiding wastage of the precious [Dongjiang] water resources and saving in pumping cost."

Hong Kong is in a challenging situation. It is dependent on Guangdong for four-fifths of its water supply, and yet does not have even "observer status" with the 'Dongjiang River Basin Authority' (DRBA), which manages the Dongjiang[96]. As an observer, Hong Kong would be able to monitor the quality and conditions of the river in China and participate in meetings concerning the Dongjiang's management, though without any right to vote.

Hong Kong's expenditure on raw water from the Dongjiang has risen consistently,in contrast to its static water tariffs

Additionally, Hong Kong pays a steeper price for water than most of its PRD neighbours. Hong Kong's expenditure on raw water from the Dongjiang has risen consistently. In contrast to Hong Kong's static retail prices (see Section 3.5), the wholesale price of water from the Dongjiang has nearly tripled, from HK$2.2 per m^3 in 1995 to HK$5.8 per m^3 in 2017. However, it should be noted that the cost is not directly transferred to the Hong Kong consumer. In fact, the local tariff system (which includes a hefty free allotment) is less progressive than fellow PRD cities, like Guangzhou (Table 1).

TABLE 1

Comparison of Hong Kong and Guangzhou's Water Tariff Systems

Source: China Water Risk, based on data from the Government of Hong Kong and Guangdong

Residential Volume (m^3)	Hong Kong		Guangzhou	
	HK$	RMB	HK$	RMB
0-12	0.00	0.00	2.30	1.98
13-26	4.16	4.84	2.30	1.98
27-34	4.16	4.84	3.45	2.97
35-42	4.16	4.84	4.59	3.96
>43	6.45	7.50	4.59	3.96
>62	9.05	10.52	4.59	3.96

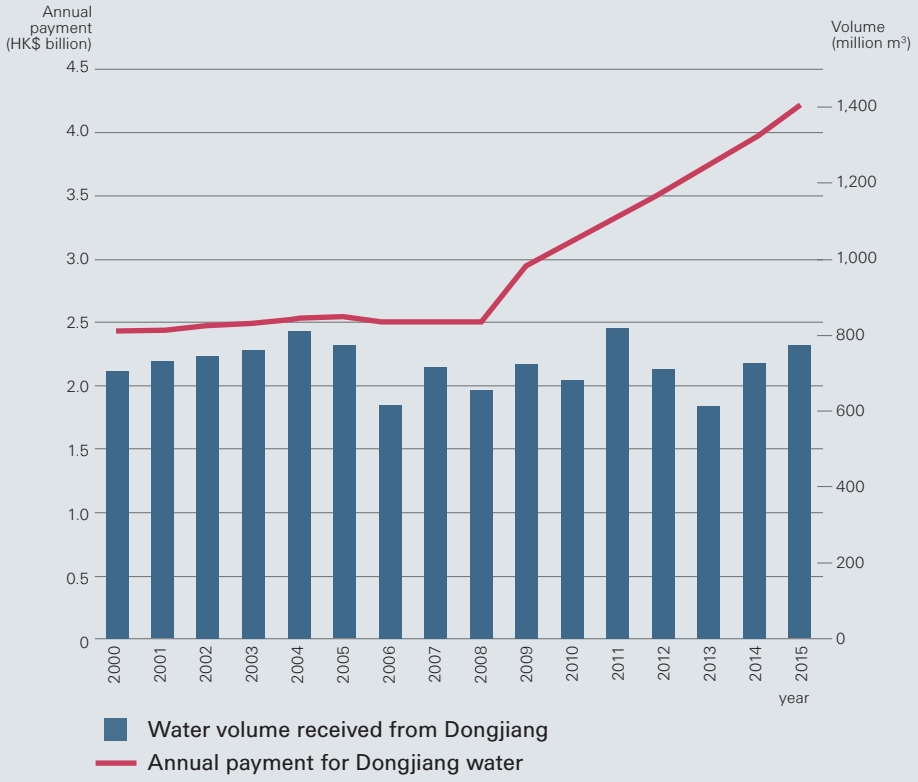
In the last set of negotiations the lump-sum payments made in three-year tranches, were ratcheted upward, from HK$11.24 billion (for 2012-2014)[99] to HK$13.49 billion (for 2015-2017)[100]. Subdivided annually, Hong Kong will continue to pay a steadily increasing rate for water withdrawals. The price increased by 6.65% from 2014 to 2015, and would rise by an additional 6.36% in 2016 and 6.38% in 2017 (Chart 3).

Thus, per unit, Hong Kong pays a comparatively large amount for this water. In 2015, it paid GI HK$4.22 billion – 3.3 times more than Shenzhen and Dongguan combined, for 34% less water.[101] Compared to Macau, which gets 97% of its water from China, Hong Kong pays 50% more for its raw water.

CHART 3

ANNUAL SUPPLY FROM THE DONGJIANG AND THE ANNUAL PAYMENT TO GUANGDONG INVESTMENT

Source: ADMCF, based on data from WSD Annual Reports, 2000-2017; GI, 2015



Freshwater is a valuable resource and is fundamental for the survival of nearly every organism on the planet, and it is not unreasonable to value and price it accordingly. Further, Hong Kong can afford such a levy. It is, however, reasonable to expect Hong Kong to pay only for the water it receives, rather than for an allotment it has avoided using.

3.2 Hong Kong Government Performance, Uninspiring over Two Decades

3.2.1 Lack of Policy and Clear Water Management Strategy

Hong Kong lacks a coherent water policy on water management and water security

Unlike most countries and jurisdictions, the Hong Kong government does not have a coherent water policy. In fact, at a policy level it has paid little attention to the issue, with only sporadic mention of water management in its annual policy addresses over the past 20 years. The DevB's policy objective in relation to water management has been to ensure the provision of a reliable, adequate and high quality water supply through an efficient water supply service. Arguably, this target is being met. However, there appears to be relatively little consideration of the longer-term sustainability of the supply, for either Hong Kong or its PRD neighbours.

China has strengthened its water regulations and policies to protect its threatened water resources

This contrasts with China, which has a long history of hydrological engineering and water management[100]. In recent years, the Chinese government has strengthened its water regulations and policies in an attempt to protect its threatened water resources.[101]

In his 2016 Policy Address, Chief Executive Leung Chun-ying vowed to address key environmental issues "vigorously" and "proactively," and expressed his administration's commitment to "supporting sustainable development."[102] He further stated the government's intention to "promote a water-friendly culture,"[103] especially with regards to consumption at mega-events, and to address regional sea pollution. This would seem an unusual emphasis given, for example, the significance of domestic consumption.

In his 2017 Policy Address, the Chief Executive's focus was on responding to the 'lead-in-water' scandal, including formulating a holistic plan to safeguard drinking water quality and put forward proposals on introducing legislation on drinking water safety. Water security, however, was not mentioned.

Despite the lack of a coherent water policy, the government has formulated a strategy (Box 4). The 'Total Water Management' (TWM) Strategy was announced in 2003, three years after Guangdong implemented its 'Water Allocation Plan', in response to vast, unsustainable withdrawals that threatened the Dongjiang in the early 2000s (see Section 1.2).[104] In 2005, the WSD commissioned a study considering the suitability, environmental impacts, social acceptability and costs of conservation strategies. It was adopted and officially launched in 2008.[105]

BOX 4

Key initiatives under the Total Water Management Strategy

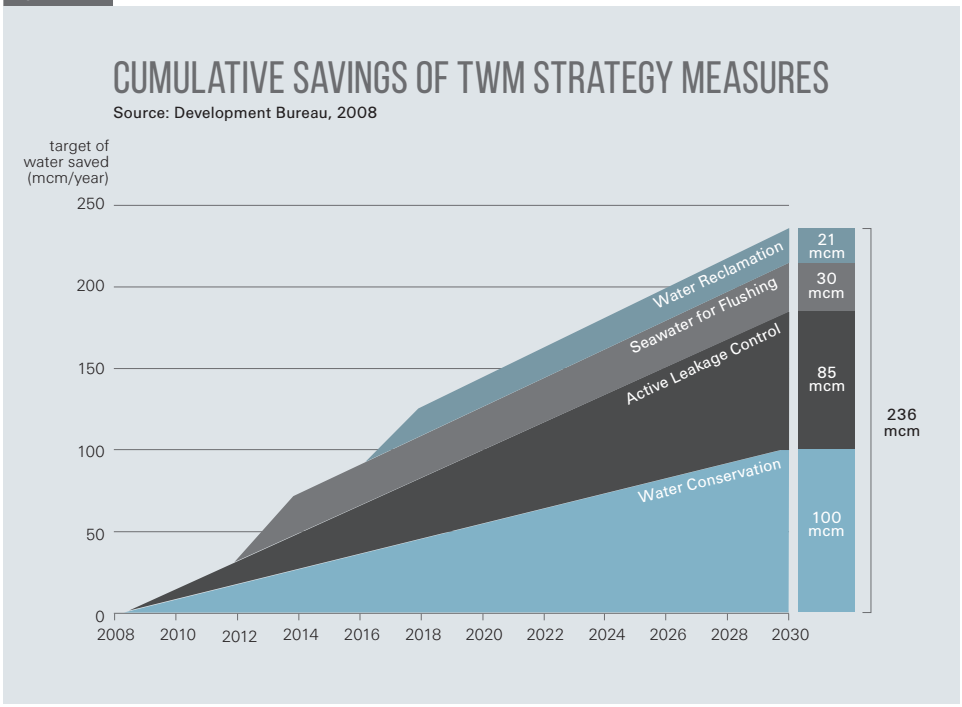
Source: Development Bureau, 2008

Water Supply Management	Water Demand Management
To strengthen protection of water resources	To enhance public education on water conservation
To actively consider water reclamation (including reuse of greywater and rainwater harvesting)	To promote use of water saving devices
To develop the option of seawater desalination	To enhance water leakage control through the programme
	To extend use of seawater for toilet flushing

The government's Total Water Managements Strategy is intended to save a volume of freshwater equivalent to a fifth of projected consumption

The TWM Strategy places emphasis on containing the growth of water demand by promoting water conservation through public campaigns and education. It has since introduced a variety of initiatives. Through a four-pronged approach, the TWM Strategy is intended to reduce annual consumption by 236 million m^3 of freshwater by 2030 (Chart 4) – equivalent to a fifth of projected consumption. Over this period, the WSD has forecasted that demand by 2030 will exceed current levels by 13%.

CHART 4



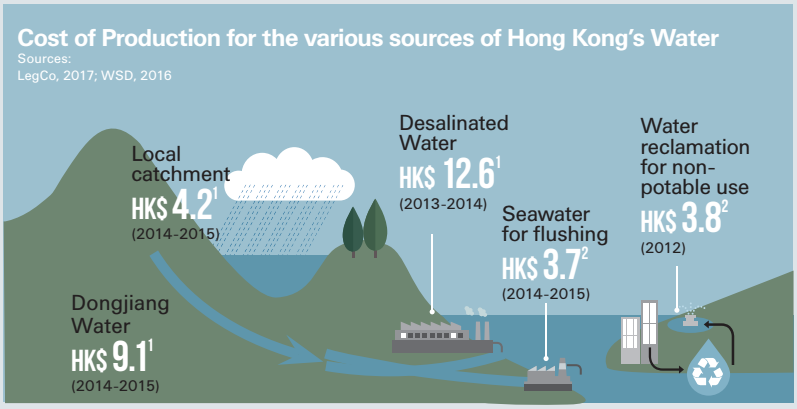
In combination with its plans to reduce demand and better manage existing supplies, the government has sought to diversify the water sources Hong Kong relies upon, also known as 'taps'. Desalination, water reclamation, greywater recycling and rainwater harvesting were all proposed for further consideration and development. These three taps, in concert with the local yield, Dongjiang raw water and use of seawater for flushing, are intended to bolster and enhance the resilience of the local water system and reduce pressure on China's increasingly stretched water resources.

Not all of these strategies are new to Hong Kong nor are they optimal. Desalination, for instance, was deployed in the 1970s, but was decommissioned within six years, after being outcompeted by the bargain prices for raw water from the Dongjiang (Box 5). Researchers have provided evidence that use of seawater in flushing, rather than reclaimed water, has fostered lax demand management, as well as adding to the energy and infrastructure costs of the water system[106,107,108] (see Section 3.3.2).

BOX 5

Planning for Desalination - Prioritising the Right Tap for Hong Kong?

Source: WSD, 1978; 2016; McArthur, 2010; WSD and Black & Veatch, 2015; Environmental Assessment Division and Environmental Protection Department, 2015; EIA Subcommittee Secretariat, 2015; AC, 2015; Government of the Hong Kong SAR, 2013; Environment Bureau, 2017; Global Water Intelligence, 2011



Desalination is not new to Hong Kong. Between 1975 and 1981, the Lok On Pai Desalting Plant (LOP), near Tuen Mun, was reportedly capable of producing up to 181,800 m^3 of freshwater per day - equivalent to approximately 7% of today's freshwater demand. It was among the largest desalination facilities in the world at the time. However, the LOP facility was decommissioned just six years after opening, having been outcompeted by the significantly lower-priced and less energy-intensive Dongjiang water supply. The final cost in 1981 was HK$8.36 per m^3 – eight times higher than the original estimate.

Preliminary investigations into revitalising desalination began in 2000. By 2007, 'Area 137' in Tseung Kwan O (TKO) was identified as an optimal site for a desalination plant. In 2012, the WSD engaged engineering consultants Black & Veatch to outline plans for the site. The Director of the WSD justified the choice of Area 137 by reason of its proximity to population centres, thereby decreasing the expected pumping costs. Further, the TKO Primary Fresh Water Service Reservoir is less than 8.5 km away, providing an ideal store for the desalinated water produced.

When it is completed (the exact schedule remains unclear), the TKO desalination plant will use reverse osmosis to produce 135,000 m^3 of freshwater per day. Further expansions are already under consideration, which could boost the plant's capacity to 270,000 m^3 per day. The initial phase is intended to satisfy 5% of Hong Kong's freshwater demand.

However, the desalination plant is only intended to operate at capacity during periods of drought. Yet the plant would need to be kept online, in 'hot standby' mode, running at potentially 10% capacity to ensure the facility is operational and maintained, the water quality is in line with regulations and that the facility can produce water as soon as it is needed to offset shortages.

The desalination plant has already proved a costly option. Between 2012 and 2016, the WSD's expenditures in consulting fees, design and planning works amounted to HK$38.5 million. Through 2016/17, an additional HK$80.2 million was spent on the further planning. In total, the WSD will have spent HK$118.7 million in five years, on planning the TKO desalination facility, before construction has even started. The proposed schedule for starting construction is within the first quarter of 2018 and the WSD has estimated that the plant will cost HK$9.3 billion to build.

Once operational, the plant will continue to incur significant costs (Table 2). Desalinating local seawater is likely to cost approximately HK$12.6 per m^3 (including distribution and customer service costs), i.e. 39% higher than the cost of raw water from the Dongjiang (HK$9.1 in 2014-15). Of this, almost a third is attributed to energy.

However, static figures fail to account for fluctuations in electricity prices, which is a critical consideration as reverse osmosis is energy-intensive and thus also has implications for emissions, which contribute to climate change. The Director of Water Supplies stated in 2013 that rising electricity tariffs will prevent significant declines in the price of desalinated water "in the near future."

It is expected that increasing take-up of technology and rising premiums on other sources will make desalination an increasingly viable option. However, the technology is vulnerable to a variety of environmental and quality issues, with the cleanliness of proximal water of paramount importance.

TABLE 2

Unit Production Costs of the Proposed Desalination Plant

Source: WSD, 2016

		HK$/$m^3$	HK$/$m^3$
(i)	Energy Cost	3.6	
(ii)	Capital Cost	4.6	
(iii)	Treatment Cost (excluding Energy Cost)	1.9	
	Unit Production Cost excluding distribution and customer servces		**10.1**
(iv)	Distribution Cost	1.9	
(v)	Customer Services Cost	0.6	
	Unit Production Cost including distribution and customer servces		**12.6**

Note: Prices in 2013/14

If the WSD's 10L water-saving campaign reaches its target, potential savings would amount to only 2.6% of annual freshwater consumption

One of the few large-scale initiatives deployed by the WSD to address consumer behaviour is the 'Let's Save 10L Water' campaign. Under the scheme, participant households receive pairs of flow controllers[109,110] and individuals are encouraged to pledge to reduce consumption. However, there is no effective means of tracking progress. It is also unclear what overall savings the government is aiming for through the campaign, raising the important question as to why. Experts have pointed to the prevailing water governance structure as hindering the development of such long-term demand side strategies, as well as insufficient resources and authority within the WSD commensurate with the demands of such a task[111].

As the campaign is a component of the TWM Strategy, it appears likely that the WSD hopes to recruit Hong Kong's entire population to the programme by 2030. If successful, the potential savings could amount to 29.23 million m^3 per year – equivalent to one-third of the 'Water Conservation' target (Chart 4).[112] Based on the WSD's projections, however, this would equate to just 2.6% of annual freshwater consumption in 2030 (see Section 3.4).[113]

Strategy that over-emphasises water supply rather than demand needs reappraisal

The TWM Strategy is the government's catch-all concept for addressing Hong Kong's water management. Yet, whilst macro-scale goals have been set, there is little evidence of effective programmes or initiatives to meet them, or the progress that has been made to date. Strategically, over-emphasis on water supply rather than demand management has failed and needs reappraisal.

Indeed the TWM Strategy may be faulted for not incorporating the social goals of water resource management such as those advocated by the United Nations (see Section 4.4.1). However this is somewhat of a 'chicken and egg' situation. Without an effective policymaking body and accompanying policy, an informed and comprehensive strategy will likely remain out of reach.

In 2014, the WSD hired consultants to review the TWM Strategy with a view to helping the department formulate a "long-term water management strategy in addressing future challenges and uncertainties"[114], extending its plans to 2040 and evaluating its experiences to date[115]. According to the WSD's annual report 2015/16, greater consideration will be given to "the potential impacts of climate change, as well as the competition among various cities in Guangdong Province for Dongjiang water resources and the projected growth of Hong Kong's population". Research and development of water reclamation, for instance, is being piloted at facilities in Shek Wu Hui, Sheung Shui and Fanling, while desalination is nearing its first stage of deployment. The results of the review are expected in 2017.

To its credit, the WSD does appear to be reorienting its own priorities, striving to better understand the macro-scale water landscape. Its latest annual report was entitled 'Water Security and Climate Resilient Development'. However, despite the strong rhetoric on the cover, little insight was provided on exactly how the challenges were to be overcome, other than through the TWM Strategy.

3.2.2 Policy to Ensure Water Supply to Point of Connection, Not to Tap

Hong Kong has rigorous quality monitoring and treatment procedures

According to the DongShen Agreement, raw water supplied to Hong Kong should conform to China's national standard set out for 'Type II waters,' which is applicable for withdrawal for human consumption[116]. The WSD tests the water at its Muk Wu Pumping Station, assuring its quality at the border (Box 6). The water is then distributed to one of Hong Kong's 21 treatment works.

BOX 6

Monitoring Water Supplies

Source: WSD, 2016,2017; WHO, 2011; Government of the Hong Kong SAR, 2001

The government employs a team of 250 to conduct water quality monitoring. Water samples are drawn throughout the distribution network, including at water treatment works, from service reservoirs, at connection points and from consumer taps. In 2015/16, 173,538 water samples were taken.

Since August 2012, the WSD has monitored the quality of Hong Kong's treated potable water in accordance with the World Health Organization's (WHO) 'Guidelines for Drinking-water Quality.'

The WHO recommends monitoring the concentrations of 89 heavy metals and chemicals in drinking water "that will not result in any significant health risk to a consumer weighing 60 kg over a lifetime consumption of 2 litres per day for 70 years.

The water quality of the entire water supply system up to this point is monitored according to physical (i.e. pH, colour, temperature, turbidity), chemical, bacteriological, biological, microbial and radiological tests conducted by the WSD's Water Science Division.[117,118,119]

BOX 7

Low Confidence in Local Water Quality

Sources: Yin and English, 2001; Government of the Hong Kong SAR, 2015

The notion that water supplied in Hong Kong is poor quality and must be heavily filtered and/or boiled before drinking is in part a lingering legacy from when disease-spreading pathogens were common in the supply. The practice of boiling was popularised in 1896, by the government, who issued advisements to boil water intended for drinking.

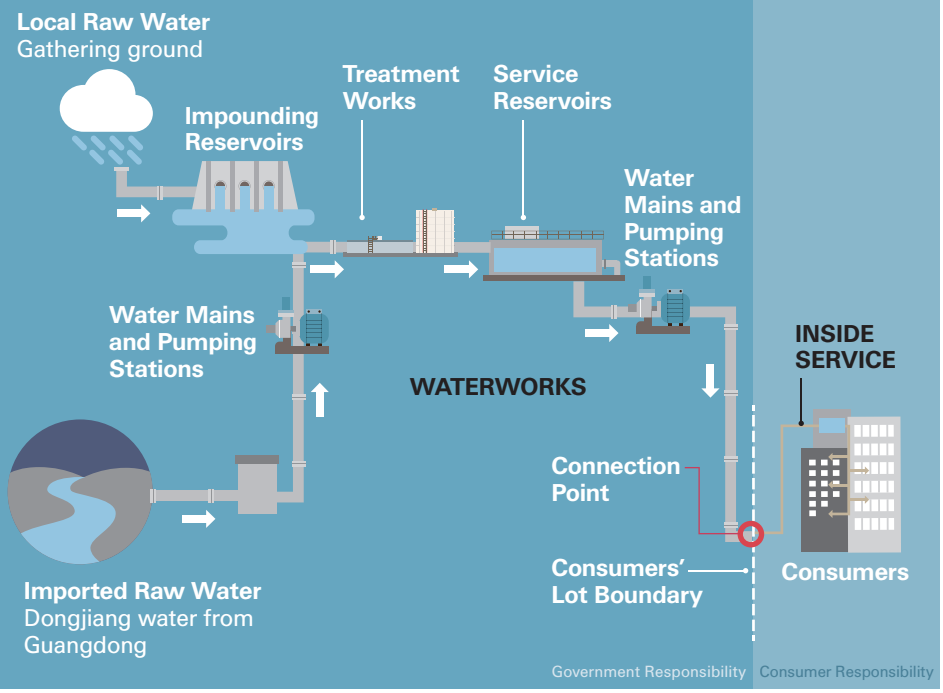
Despite both the eradication of the most harmful diseases from the water supply and the fact that today the government itself considers Hong Kong's supply to be one of the world's safest, there is still a commonly held misconception amongst the public that practices such as boiling water remain necessary. This belief is exacerbated by, and to some extent explicable as a result of incidents such as the recent 'lead-in-water' scandal (see Box 10) and current government policy to assure the quality of potable supplies only to the point where it reaches the "inside service" of buildings, i.e. building connection point, and not to the tap (Figure 7).

Notwithstanding strict monitoring procedures, the Administration received 1,817 complaints about dirty and discoloured water and 214 complaints about taste and odour in 2015 (Box 7)[120]. The majority of these issues were linked to plumbing within private properties – the "inside service" – and thus fall outside the WSD's purview (Figure 7).

FIGURE 7

SCHEMATIC OF HONG KONG'S WATER SYSTEM

Source: Legislative Council, 2016



The WSD's responsibilities focus on managing water supplies to the point of building connection, but do not extend to the tap

At this juncture, the 'Consumer' or 'Agent' is responsible for proper maintenance of the supply. However, it is this final part of the supply system where the majority of mismanagement, including poor servicing and substandard plumbing results in high quality potable water being contaminated. Importantly, it also allows losses such as leakage and illegal connections to go undetected (see Section 3.3).

In other countries, such as the United Kingdom (UK) and Singapore (Box 8), water is guaranteed to a high standard to consumers' tap, with the assurance that it will not have a negative impact on consumer health.

Losses from private premises will continue to be problematic if the government does not change it source to connection policy

As long as the WSD remains largely uninvolved in the critical final phase of water delivery, the integrity of the water systems on private properties will continue to blight the system. In addition, it will undoubtedly result in increasing negative perceptions of the WSD.

BOX 8

Assuring Supply from Source to Tap – UK and Singapore

Source: Drinking Water Inspectorate, 2009; Research Office, 2016; Legislative Council, 2016

Although formal responsibility ends, as in Hong Kong, at the threshold of private property, water providers in the UK conduct approximately 2.5 million tests per year, one-third of which are on water that is discharged from taps in private residences.

The legal basis for this came through the UK's 'Water Fittings Regulations' of 1999, which gave water companies permission to inspect private premises to ensure mains water quality will not be impacted by any backflow of water contaminated on a private property. It has ensured that water providers are aware of water contamination issues within private premises and can then make recommendations to remediate or prosecute negligent parties.

Singapore has also established a "comprehensive sampling and monitoring programme" to ensure the quality and integrity of its water – from source to tap. The nation has a dedicated 'Drinking Water Unit,' which operates in accordance with the 'Code of Practice on Piped Drinking Water Sampling and Safety Plans,' ensuring the highest standard of water through to delivery and consumption. The PUB conducts 400,000 tests throughout its network, plants, at connection points and outlets on private properties, and achieved 100% compliance with WHO standards between 2008 and 2014.

3.2.3 A Complicated Management Structure, Too Many Cooks

The government's Audit Commission has found the WSD to be underperforming for nearly two decades

Part of the challenge for the WSD, as it considers implementing a robust, accountable series of policies and initiatives, is the way in which the government operates. The Hong Kong government follows a traditional vertical structure, which can complicate inter-departmental operations and collaboration. This structure is evident in the departments and branches charged with the management of local water resources.

Although the WSD is the sole government authority responsible for managing water supply and regulating water quality, given the complexity and multifaceted nature of the water system, multiple departments may be involved at any one time. Coordination has presented a challenge. Whilst the WSD is the highest authority on water issues, it is also beholden to the mandates and stipulations of other authorities like the ENB. In any one of its efforts to undertake tasks as simple as maintenance, it could be subject to the bureaucracy of three or more departments.

For instance, the 'Joint Office on Water Seepage' (JO), a collaboration between the FEHD and DevB, has taken point on issues of water seepage on properties. It is one of a number of cooperative bodies within the government that have been established to limit miscommunication and smooth collaborative efforts.

The pilot programme was initiated in 2006, in response to public complaints about water seepage.[121] The JO was intended to handle such complaints about water seepage on private property. However, according to a 2008 investigation conducted by the Office of The Ombudsman, its service had been far from optimal.[122] A key conclusion of the investigation was that the "BD, FEHD and WSD, together with their bureaux if necessary, [need] to work out some mechanism to resolve their differences on enforcement responsibilities."[123]

Subsequently, in its 2016 report, the AC determined that the JO's performance had continued deteriorating. Response times had been increasing, leak source-identification success had been in decline, inter-district recordkeeping and communication with the relevant departments had been insufficient[124] – only 33% of cases between 2011 and 2015 requiring further attention were forwarded to the WSD.

Insufficient co-ordination and unclear responsibilities likely account for the lack of a coherent water policy in Hong Kong

Insufficient co-ordination and unclear responsibilities also likely stem from the lack of a coherent water policy. Research by the Organisation for Economic Co-Operation and Development (OECD) indicates fragmentation of tasks and lack of vision is the most prominent policy gap in urban water governance (Box 9).

BOX 9

OECD on Water Governance: Fragmentation and Policy Silos

Source: OECD, 2016

"Cities reported that fragmentation of tasks and the lack of strategic vision across water-related sectors as the most promient policy gaps to urban water governance. Similarly, unbalanced powers between authorities representing different interests (e.g. rural and urban areas) may hinder co-ordination. The lack of legislative co-ordination may also impair water quality, because harmful legislative prevails over legal dispositions meant to prevent or remedy the problem. Overlapping or unclear responsibilities generate grey areas resulting in high transaction costs and delays."

Regulatory gaps also exist. Neither the Waterworks Ordinance nor its subsidiary Regulations, for example, regulate the standards of water quality.[125] This is addressed only by the WSD's pledge to supply water in compliance with WHO guidelines[126], but this has been inconsistently adhered to, as demonstrated by the 'lead-in-water' incident (Box 10).

The underperformance of the department has also been highlighted by investigations conducted by independent agencies, such as the AC and Office of The Ombudsman.

The WSD has been underperforming for nearly two decades[127]. It has fallen short of quality targets[128], missed deadlines[129], struggled to address

BOX 10

Case study – The 'Lead-in-Water' Incident: Highlighting Government Performance Concerns

Source: Chan and Lai, 2016; WSD, 2016

The 'lead-in water' scandal serves to illustrate some of the performance shortcomings of the WSD. In particular, the incident highlighted the poor delineation of various departments' role and responsibilities, unclear policies and ordinances regarding supplying private premises, the lack of transparency and accountability of the parties involved, as well as revealing an institutional resistance to change.

The incident came to light in 2015, when government water quality testing revealed excessive quantities of lead in domestic supplies in eleven Public Rental Housing (PRH) estates. With approximately 30% of Hong Kong residents residing in PRHs, concern rapidly spread that this was unlikely to be an isolated incident. Indeed, further testing by the Hong Kong Productivity Council indicated up to 1,000 more buildings were likely to be affected.

A Commission of Investigation (COI) was convened to determine the causes, review the adequacy of existing monitoring systems and provide recommendations to prevent such an incident reoccurring.

The Commission heavily implicated the WSD, Housing Authority (HA) and Housing Department (HD). In particular, the WSD was criticized for:

(i) Lack of clear responsibility over the quality of drinking water at the tap. The COI accused the WSD of "shirking its responsibility," and of adopting an attitude that the water contamination was the "HD's problem," in part evidenced by the WSD changing its pledge from providing quality drinking water "from source to tap" to "from source to distribution."
(ii) Lack of understanding of WHO guidelines.
(iii) Failure to develop and implement a sound Water Safety Plan (WSP).
(iv) Failure to exercise legal powers, citing the lack of enforcement against contractors failing to comply with statutory requirements.
(v) Failure to update legislation, making it challenging to determine the precise responsibilities of the various departments.
(vi) Failure to uphold the quality of contractors' service. On paper, there appeared to be a "perfect multi-barrier checking system," whilst in reality it was no more than a "classic case of buck-passing."
(vii) Failure to adopt a proper sampling protocol.

Recommendations included (but are not limited to):

(i) Reviewing the adequacy of the existing legislative framework and regulatory regime, in particular whether the responsibilities should be confined only to drinking water quality up to the point of connection.
(ii) The need for delineating water supply and water quality responsibilities.
(iii) Establishing an independent water body to oversee the WSD's performance.
(iv) Establishing and implementing a WSP.
(v) Reviewing WSD's control mechanism on construction projects.
(vi) Establishing robust systems to monitor compliance.

Directly in response to the 'lead-in-water' incident, the WSD initiated a review of the Waterworks Ordinance and Regulations. A consultation paper was published in September 2016.

leakage[130], failed to maintain high training standards[131], engaged the public poorly[132], struggled with DongShen Agreement negotiations[133], hired substandard contractors[134], inconsistently regulated and educated industry[135], understaffed key initiatives[136] and has rarely acted proactively.[137,138,139]

3.2.4 Drought Contingency, a Confidential Plan

The WSD's 'Drought Contingency Plan' has not been disclosed to the public or LegCo

In recent years, the WSD's annual reports have alluded to a 'Drought Contingency Plan' (DCP).[140] The government's so-called "adaptive measure" is designed to "guarantee our readiness" and "efficiently mobilise resources" either in Hong Kong or China. The DCP has not been publically disclosed and our research indicates that few details are known to anyone, including LegCo, outside of the government[141].

The DSD, conversely, has outlined its plans for flooding. Numerous presentations, pamphlets, videos, and technical reports are available to the public, allowing proactive citizens to familiarise themselves with the best practices, the DSD's procedures and the systems in place to limit exposure to hazard.

This secrecy contrasts with comparable cities around the world, where governments, keen to garner support and promote an image of proactivity in the face of climate change, have published and distributed similar plans. For instance, it has been commonplace in dozens of states and cities across the United States to publish their drought mitigation plans online, with indices detailing varying levels of severity and appropriate actions.[142]

In response to enquiries about the DCP, the WSD has provided only a few lines summarising aspects of the plan,[143] which appear to call for:

(i) Strengthening communications with Guangdong authorities regarding the water level and flow rate of the Dongjiang river;
(ii) Making requests to Guangdong authorities to increase the amount of Dongjiang water supplied to Hong Kong;
(iii) Stepping up the monitoring of water quality in impounding reservoirs; and
(iv) As necessary, adjusting the treatment process to cope with the deteriorated raw water quality.

In drought conditions, Hong Kong's allocation will remain unchanged, while all neighbour cities face up to 15.4% reductions

The lack of apparent emphasis on management or conservation initiatives within Hong Kong is inconsiderate to neighbouring urban centres within the PRD, assuming that they will have sufficient water to bail out Hong Kong. While Hong Kong can receive up to 1.1 billion m^3 of raw water from the Dongjiang even under drought conditions[144], every other city relying on the Dongjiang would face reductions of between 3.2% and 15.4% in their allocations.

This over-allocation appears unsustainable, even from the government's own perspective. In 2014, the Development Bureau stated, "In the event of drought, there would be no guarantee that the [Guangdong] side could meet our demand for a higher [Dongjiang] water supply quantity."[145]

Furthermore, no information on rationing or communication with the public was provided, raising the question as to whether these issues have been omitted from the plan. In its 2015/16 annual report, the WSD indicated that it had also been formulating a "Crisis Management Plan" (CMP) and several other contingency plans, in addition to the DCP. However, even less is known of what these strategies might entail as they are "confidential"[146]. The CMP is far broader that the DCP insomuch that it deals with "any incident that will causes serious interruption of water supply or water quality issues"[147]. What is known is that it "lays down the details of emergency classification, activation mechanisms, crisis management structure, operation modes, venues and logistic arrangement and duty rosters."

3.2.5 Water Intelligence, Not-so-smart Metering Fails to Accurately Monitor Consumption and Losses

As the domestic survey of 2011 demonstrated (Box 1), monitoring actual consumption has been an ongoing challenge for the WSD (Box 11).

The government's 'Water Intelligence Network' aims to address meter inaccuracy and reading errors, improve accountability and increase consumer awareness

Seeking to address meter inaccuracy and reading errors, and improve accountability and consumer awareness, the government has been preparing to establish a 'Water Intelligent Network' (WIN). The preliminary work for establishing such a network-wide system began in 2005.[148]

According to the WSD, network management measures covered under the WIN include:

(i) Active leakage detection and control through the usage of the monitoring and sensing equipment installed in the networks;
(ii) Pressure management to reduce the pressure in the networks if appropriate;
(iii) Quality and speedy repairs to water main leaks and bursts; and
(iv) Asset management by reprovisioning of aged water mains which are beyond economic repair with a view to maintaining the healthiness of the networks.

BOX 11

Accurately Monitoring Water Consumption Proves Challenging

Sources: AC, 2011; 2015; Government of the Hong Kong SAR, 2008; Office of The Ombudsman, 2011; DevB and WSD, 2015

Between April 2005 and October 2007, old and defective water meters were replaced in response to 85,666 complaints about overcharging. Nearly 40% were found to have valid grievances. The "excessive charges" amounted to HK$38.07 million. Subsequently, around 230,000 meters were replaced in 2006/07 and a further 370,000 in 2007/08.

By July 2011, the government had installed about 2.8 million small domestic water meters throughout Hong Kong and 34,000 large meters at non-domestic sites. Despite these efforts, an investigation undertaken by the AC found that 17.64 million m^3 of freshwater was unaccounted for in 2010, due to inaccurate metering.

In 2010/11, the Office of the Ombudsman found just 5% of meters were failing accuracy tests, estimating as many as 138,000 were gathering inaccurate data. The WSD exchanged over one million meters between 2011 and 2015, improving consumption estimate accuracy across Hong Kong from 95.3% to 97%.

It should be noted that metering issues are cyclical, with the mechanisms becoming less accurate as they age, and are damaged, needing replacement every few years. Large meters have an optimal service life of 4-7 years, while smaller meters can function for 12 years or more, all the while becoming less accurate.

In 2011, the Ombudsman found that meter readers (MRs) had received insufficient training resulting in mishandling of readings, defective meters and billing issues. MRs take 400-500 meter readings per day. In 2010/11, there were irregularities in 323,366 instances. Whilst this is a significant number, it admittedly represented just 3.9% of over 8.3 million routine readings.

Under the WIN concept, DevB and WSD are also developing the centralised 'Intelligent Network Management System' (INMS), to monitor and control freshwater and flushing water supplies. In addition, the INMS is intended to collate data from the 'Automatic Meter Reading' (AMR) system.

The AMR system provides metering data, "status outputs" and alert signals, which sync with the WSD's servers via communications networks such as 3G/4G and internet Virtual Passport Networks (VPNs). It is also intended that private meters will sync with consumers' phones and Internet accounts, thereby empowering them to monitor their own consumption, clarify charges, spot leakages and assist in planning. It is ultimately perceived to be an "Ideal platform for promotion of water conservation."

In 2015, the WSD piloted its 'Smart Metering System' smartphone app, providing near real-time data and a record of recent consumption. A similar approach has been adopted by other local companies and organisations, such as Towngas.

In April 2015, the DevB revealed its intention was to "keep [its] finger on the pulse" of Hong Kong's water[149] by installing sensors in the underground network to collect data and to establish district-scale metering. Hong Kong will be subdivided into 2,000 district metering areas (DMAs), within which sensors will be installed through "minimally invasive surgery". Eight-hundred-and-fifty DMAs are already in place.[150]

This system will allow for close monitoring of bursts and leakage, as well as quantifying, in near real-time, the volumes being supplied and consumed. The vast database that will be developed will concurrently provide water managers with minable data, allowing them to predict water mains bursts, and more readily tackle faulty sections. To this end, the WSD has enlisted Data61[151], a digital research unit established by Australia's

Commonwealth Scientific and Industrial Research Organisation (CSIRO). The group is reportedly assisting the WSD mine its water network data, with targets including leak identification.

The WIN is linked to the government's overarching plans to transition Hong Kong to a 'smart city[152],' the components of which are clarified in the government's 'Hong Kong 2030+' vision.[153] However, water played a minimal role in the initial planning, with an overwhelming focus on the quality of the seawater in Victoria Harbour. Furthermore, there were only brief considerations of the integrity of local catchments, the Dongjiang, the possibility of desalination, and a mention of the TWM Strategy (released a year after).

The government also highlighted the need to deploy "blue-green infrastructure," which revolved around concepts such as "water sensitive planning and design", "sustainable drainage system" and "low impact development." Further, they proposed the necessity of improving local capture and storage of runoff and stormwater, restoring natural hydrology[154]. In a related document, the government stresses that "availability of clean water [will] affect the well-being of each and every individual of our city."[155] Yet it failed to posit clear objectives, simply promoting desalination and the conversion to the WIN system[156], and alluding to minimal deployment of rainwater harvesting and greywater reclamation[157,158].

Whilst these innovations would contribute to Hong Kong's water security and may indicate progress, the technologies are a long way from being implemented at their full capacity. The ongoing development in East Kowloon has become a hub for trials of smart city concepts for greening local infrastructure[159], promoting innovation[160] and advancing towards a 'circular economy.'[161] But it remains unclear when the technologies will be completed and ready for broader deployment.[162]

3.2.6 Accountability of Large Non-Domestic Water Users is Lacking

Aggregated water consumption figures provide macro-scale insights into the consumption behaviours and trends across local non-domestic sectors. However, without significant improvements in transparency and metrics on the specific uses to which municipal freshwater is being put, it is challenging to determine what is driving the increasing demands and how they may be managed.

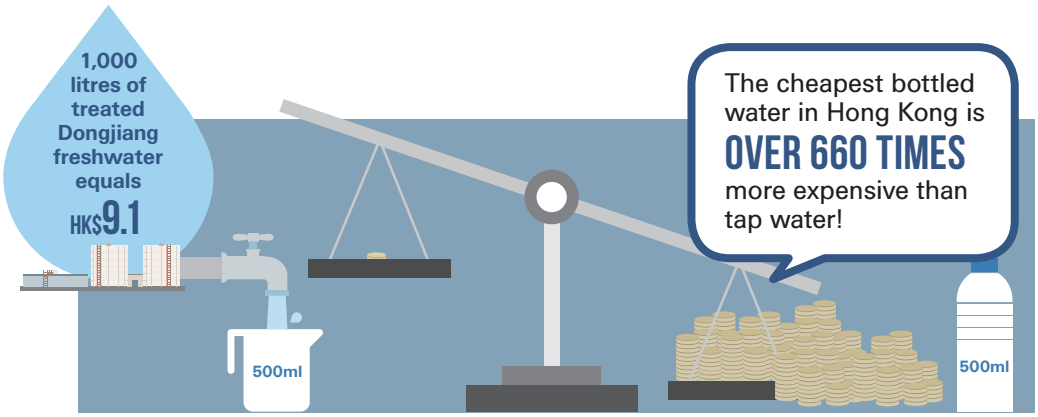
Largest water consumers in Hong Kong do not openly publish any water consumption data

By way of example, two of the largest consumers of water, the Ocean Park Corporation (a financially independent, unlisted non-profit organisation) and Watsons Water (an unlisted subsidiary of a publicly-listed Hong Kong conglomerate), do not openly publish any water consumption data. Nor have they been under any legal obligation to do so, unlike their 'listed' counterparts, who, since January 2016, must comply with the Hong Kong Exchange's (HKEx) ESG reporting requirements.[163] For listed companies heavily dependent on water, this would mean either disclosing water consumption and intensity (per unit of production, volume per facility) figures, or providing an explanation as to why disclosure cannot be made.

Many Hong Kong-based firms (both listed and unlisted) already issue annual standalone sustainability reports, or include sustainability sections within their annual reports. These reports include indicators including water use and disposal. However, many of these firms obscure their consumption of the varied types of water, failing to disaggregate water use and disposal by type, or even by country of operation[164].

Ocean Park and Watsons Water are known to withdraw considerable quantities from the municipal supply, whilst assuring consumers and investors of ambitious water conservation programmes.[165] However, the success of these programmes in limiting or offsetting their operations' consumption is not disclosed and therefore remains unknown.

The apparent lack of transparency and openness from non-domestic users is a concern because of the potentially large volumes being consumed. Effectively, they take advantage of Hong Kong's cheap water and make a profit without shouldering the appropriate fee for the volume of water they use (see Section 3.5.3).



The cheapest bottled water in Hong Kong is over 660 times more expensive than tap water

A cubic metre (1,000 litres) of freshwater from the Dongjiang, following appropriate treatment and distribution, costs approximately HK$9.1. This indicates that 500 ml of municipal freshwater unbottled costs around HK$0.0046. This heavily contrasts with even the cheapest bottled water[166], which is over 660 times more costly than the same water supplied by the WSD[167].

3.2.7 Effective Demand-Side Management Lacking

Hong Kong's demand-side targets lack useful objectives, monitoring and measurement

Effective demand-side management requires clear policy, objectives and targets, and the ability to measure and monitor performance. As noted above, these factors appear insufficient in the Hong Kong government's approach to demand-side management.

While the government does not appear to keep a detailed breakdown of domestic water use, as noted above, the WSD's Domestic Water Consumption Survey in 2011 (Box 1) represents the closest attempt to date. It sought to clarify how water was used in households[168,169] and importantly to formulate a more effective water conservation strategy. However, outstanding voids remain in the department's databases. It is, for instance, unclear which districts of Hong Kong are most problematic, as the WSD "does not have unmetered water consumption data at district level.[170]"

Although the survey was a step in the right direction, usage was not tracked with smart meters, instead relying on respondents to self-report[171]. This compromised the robustness of the study and the validity of results. The department promised regularly to conduct follow-up research, but over the subsequent six years, results from a comparable study have yet to be released.

Despite numerous outreach programmes[172] (Box 12) and over two decades of direct consumer engagement, water usage, especially for domestic purposes and per capita, has not declined but increased (Figure 3). This indicates that the current methods are insufficient and need to be reviewed and revised – clearly not enough is being done to dispel the illusion of plenty.

BOX 12

Attempts to Engage the Public

The WSD has run the 'Water Conservation Ambassador Selection Scheme' since 2008, involving 5,500 participants from 41 primary schools by 2015. Further schemes, such as the "Cherish Water Campus" Integrated Education Programme (IEP), the 'Let's Save 10L Water' campaign, and the introduction of the voluntary 'Water Efficiency Labelling Scheme' (WELS), have aimed to encourage consumers to improve their efficiency and "not waste a single drop".

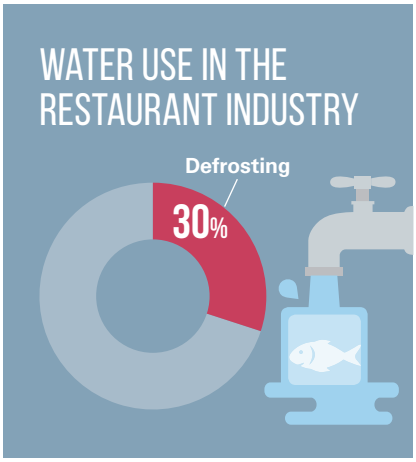
As early as 1993, the WSD also established the Customer Liaison Group (CLG), which includes domestic consumers from Hong Kong's eighteen districts, seven representatives of trades, and five guest members of government and independent charities. The CLG was formed to promote "better communication with [the WSD's] customers on their needs and their expectation of standard of service", as well as "to solicit suggestions and comments for improving the quality of our service." Convened quarterly, briefings and presentations are delivered by WSD staff on current, pertinent issues and initiatives.

As noted above, "no target date" was publically set for achieving the water-saving target of schemes like the 'Let's Save 10L Water' campaign, nor any overall target set for number of households to be involved.[173] It is assumed the department is seeking ultimately to recruit all account holders to the initiative, though this is not clearly expressed anywhere. By 2016, 140,000 households were participating[174], less than 5% of the 2.9 million domestic accounts the WSD supplies[175].

Regarding the commercial sector, cost is a significant driving factor, as would be expected. The Hong Kong Construction Association, for instance, noted that whilst major local contractors are aware that they "should be more environmentally friendly"[176], they are bound by contractual requirements, which often require use of the most cost-efficient (i.e. cheapest) options — whether in selection of materials or use of water. In other words, there are no incentives for conservation.[177]

Without sufficient incentives, few industries will voluntarily change wasteful habits

Within the restaurant industry, an EPD programme in place since 2003 encourages Chinese restaurants to use refrigerators, or thawing machines for defrosting, rather than the traditional practice of using running water[178], which accounts for about 30% of water use in the sector. However, the programme seems to have lapsed.[179] A respondent from Hong Kong's Association of



Catering Services said that some food-and-beverage outlets had no incentive to change their wasteful thawing practice because water from the WSD is so cheap. Instead they were more concerned about the DSD's sewage and effluent charges, which have risen.

Despite the lack of effective water conservation in Hong Kong, in his 2016 Policy Address, the Chief Executive commended his administration's ongoing efforts to promote water conservation through a "multi-pronged approach and more proactive strategy[180]." He cited the release of "water efficiency practice guidelines for the catering sector," and encouraged the private sector to "conduct water efficiency review[s]," as key examples.

3.3 Wasting a Valuable Resource

3.3.1 Leakage and Non-Revenue Water

Leakage has plagued Hong Kong's water distribution network for decades and, along with illegal withdrawals and inaccurate metering, contributes to what is known as 'non-revenue water' (NRW). While the government publishes figures for total water lost from the mains network, it omits any breakdown of this data from its regular publications. It fails to disclose the means by which the water is lost or unaccounted for. However using statistics made available as a result of the AC's work, it is possible to obtain more clarity as well as gain some insight to recent trends.

Statistics released by the WSD in 2010 indicated that of the water supplied that year, 20% was lost as it flowed through government mains[181]. Additionally, inaccurate meters, illegal extraction and leakage from poorly maintained infrastructure on private property accounted for 2%, 2% and 2.5%, respectively.[182] Thus, 26.5% of water supplied in 2010 was lost from the system (Chart 5).

By 2013, 31.6% of freshwater supplied was lost before reaching the consumer

In 2013, despite the government's 'Replacement and Rehabilitation' (R&R) programme (see Section 3.3.4), the AC found that losses increased to 31.6% of the freshwater supplied. The AC noted that approximately 17% of the supply was lost through leakage and bursting throughout the mains network.[183] This left around 15% that was lost by other means and parts of the network.[184] As indicated by the 2010 data, the water was likely lost through a combination of leakage from private mains (inside services), illegal extraction and inaccurate metering (Chart 5). However, the precise proportions lost to each remain unclear.

It is clear though, that the 'other losses' (as opposed to losses from government mains) had tripled in just five years, from 6.5% in 2010 to 18% in 2015. Since metering improved over the period (see Section 3.2.5) and unauthorised consumption is reportedly a "notional estimate following international practice,"[185] (i.e. the WSD does not have clear data), it is assumed that these figures remained relatively stable, at 2% and 2%. It may, therefore, be surmised that leakage on private property accounted for the greatest losses outside of the government mains.

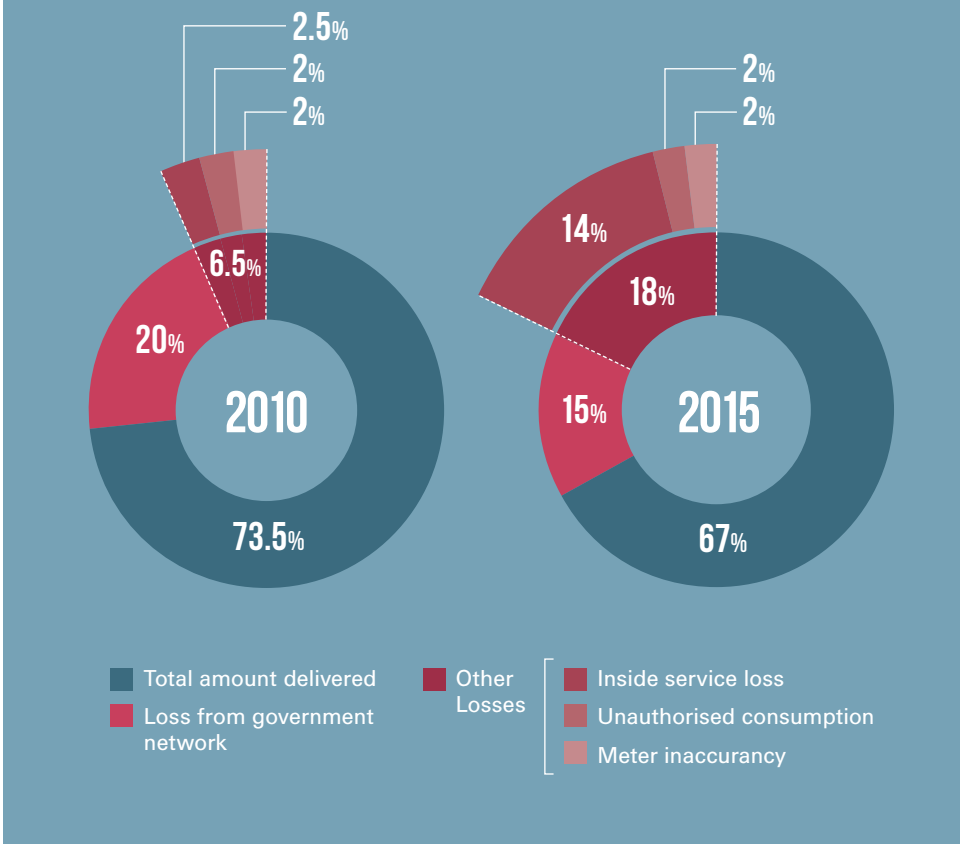
Leakage on private property potentially increased six-fold over five years

Potentially, losses from inside services increased six-fold over five years, from 2.5% in 2010 to approximately 14% in 2015. The WSD has revealed that "water loss in consumers' inside service is mainly attributed to the aging of private mains.[186]"

CHART 5

PROPORTION OF FRESHWATER METERED, LOST FROM GOVERNMENT MAINS, AND UNACCOUNTED FOR

Source: (a) Ma, 2012; (b) WSD, 2014/15; 2017



Use of seawater for flushing saved 5 billion m^3 of freshwater between 1994 and 2014

That means based on these figures, the freshwater lost from the system is comparable with (and, in numerous years, greater than) the volume of water supplied from Hong Kong's local reservoirs (Chart 6). This balance inevitably is influenced by annual rainfall.

CHART 6

COMPARISON OF WATER LOST FROM THE SUPPLY NETWORK WITH WATER SUPPLIED FROM HONG KONG'S CATCHMENTS

Source: ADMCF, based on data from WSD Annual Reports, 2005-2015, AC, 2015

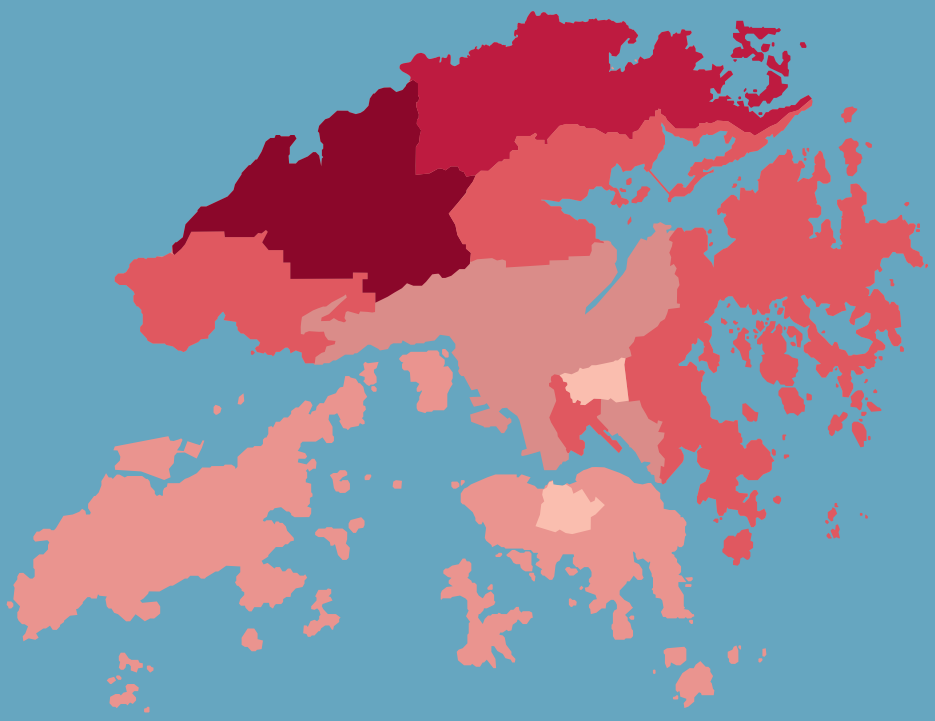
In the worst cases it has been "virtually impossible to assess the huge amount of freshwater wasted"

As of 2015, the WSD was also found lax in addressing active and ongoing leakage, even when incidents were reported (Figure 8). Approximately half of leakage cases on private property remained unresolved for more than 60 days[187]. This was despite internal instructions that a disconnection warning will be issued if the leakage is ongoing after 14 days, and must thereafter be addressed within seven days.[188] In the worst case, leakage remained unaddressed for two years, making it "virtually impossible to assess the huge amount of fresh water wasted". Lack of performance in this area also has financial implications since it was found that the WSD had not recouped "a lot of money" for repairs conducted on private properties, where leakage had been addressed.[189]

FIGURE 8

LEAKAGE INCIDENTS PER 1,000 HOUSEHOLDS IN HONG KONG (2015)

Sources: WSD, 2016-17; C&ED, 2016



District	Leakage incidents*
Wan Chai	3
Wong Tai Sin	7
Islands	11
Tsuen Wan	13
Central & Western	13
South	14
Sham Shui Po	15
Kwai Tsing	16
Sha Tin	16
Yau Tsim Mong	18
Kwun Tong	18
Eastern	19
Tai Po	20
Tuen Mun	21
Kowloon City	22
Sai Kung	24
North	36
Yuen Long	80

*per 1,000 households

3.3.2 Seawater Wears Down Infrastructure, Leading to Additional Wastage

Use of seawater for flushing saved 5 billion m^3 of freshwater between 1994 and 2014

A separate network of water pipelines convey seawater for flushing, which saved 5 billion m^3 of freshwater between 1994 and 2014. However, the seawater corrodes the pipes, joints and other mechanisms more than twice as fast as in the freshwater mains.[190] This has proven especially problematic with older pipelines, which were made from cast iron and asbestos cement. The average service life of such pipes has been around 20 years,[191] and 34% of Hong Kong's approximately 1,500 km of seawater mains are currently 20 years or older.[192]

The government, seeking to address corrosion in pipes, valves and pumps, proposed replacing defunct seawater pipelines with polyethylene in 2006. Replaced mains have a markedly increased service life, of up to 50 years, which is equivalent to that of the mild steel and ductile iron used for the freshwater transmission.

Losses from seawater pipes were as high as 28.3% of supply in 2013

As recently as 2013, however, losses from seawater mains pipes were as high as 28.3%[193]. This was significantly higher than the 17% that escaped from the freshwater mains that year, which is itself up to three to four times the leakage rate in many other cities in Asia. Whilst this is not an issue of freshwater loss, it results in energy wastage, with financial consequences.

3.3.3 The Cost of Non-Revenue Water

Between 2004 and 2015, the WSD may have lost more than HK$17 billion of potential revenue from its unmetered freshwater

Water lost from the system inevitably adds to the costs of the supply, a cost which is absorbed by the government, and thus taxpayers. At the rate of HK$4.58 per m^3 (a standard established by the AC[194]), unmetered freshwater could have represented HK$1.35 billion in lost revenue for the WSD in 2013. Between 2004 and 2015, the WSD may have lost as much as HK$17 billion of potential revenue from its unmetered freshwater alone.

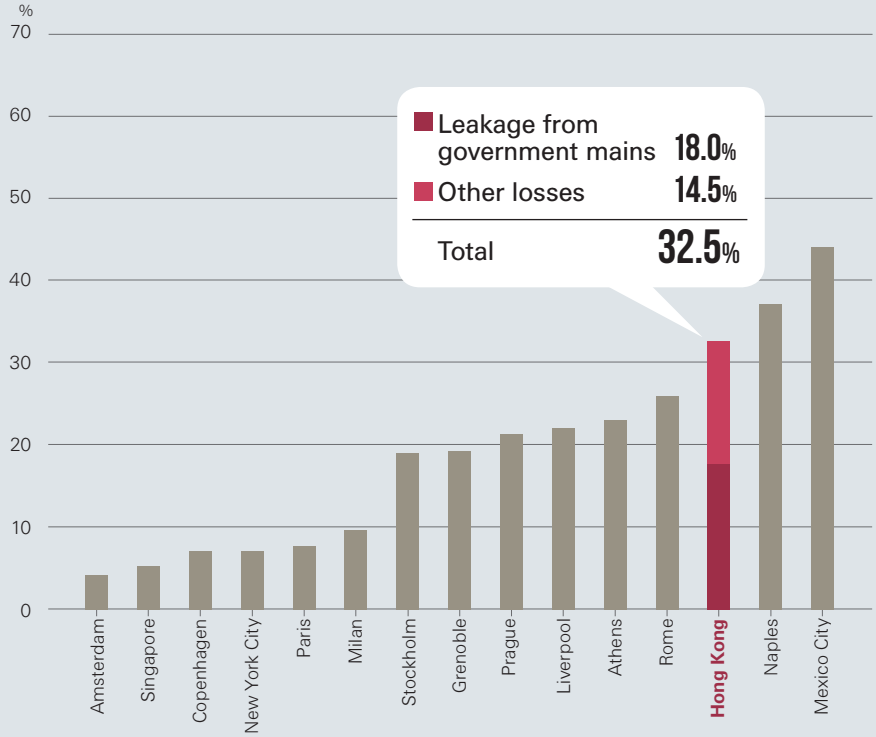
3.3.4 Plugging the Gaps, A Problem Part Solved?

In 2000, seeking to address the loss of more than a quarter of mains water[195], the WSD initiated a large-scale R&R programme.[196]

CHART 7

PROPORTION OF WATER LOSS IN SURVEYED CITIES (2012)

Source: OECD, 2016; WSD, 2014



The department had completed 91% of the repair work by February 2015[197], resulting in mains leakage reaching the stated target of 15% on schedule (Box 13).[198,199]

BOX 13

Rehabilitation and Replacement of Hong Kong's pipes

Sources: AC, 2010; WSD, 2015

By March 2010, 41% of WSD's water network had been repaired, resulting in a decline in leakage incidents of around 40% from over 21,000 in 2000. Further, pipe bursts declined more than 60% over the same period. An audit revealed that 8% of bursts between 2007 and 2010 stemmed from faulty materials and 50% of bursting occurred as a result of ground settlement, mostly due to improper filling around the pipes.

In 2015, 33% of Hong Kong's freshwater was lost from the system

The success of the WSD in achieving its 15% target at first glance appears impressive. However, the overall leakage data suggests that although the government mains were repaired, metering improved and illegal withdrawals have been stable and minimal, leakage on private property increased (Chart 5) and appears to have been neglected. In 2015, 33% of Hong Kong's freshwater was unaccounted for, amounting to 321 million m^3 of freshwater.[200]

Hong Kong's water leakage is considerably higher than even cities in developing nations

Hong Kong's leakage also remains considerably higher than the rates observed in similarly wealthy and developed world cities (Chart 7). Tokyo, for instance, reduced its leakage rate from 20% in 1955[201] to 2.7% by 2010. Hong Kong's leakage rate is comparable to less economically developed cities throughout Asia, where an average of 30% of water produced is lost.[202] According the United Nations Educational, Scientific and Cultural Organization, Phnom Penh, hampered by corruption, inadequate infrastructure and ranking 99 places below Hong Kong in terms of 'liveability'[203], apparently reduced its 'unaccounted-for water' from over 60% in 1998 to 6% by 2008.[204]

If realised in its current form, the TWM Startegy would address less than 40% of Hong Kong's losses from government mains

Looking forward from 2008, the WSD set itself the target of achieving an annual saving of 85 million m^3 by 2030, under the TWM Strategy[205]. This amount would equate to just 58% of the losses from government mains in 2015 alone, and is therefore not aspirational. Indeed, through the R&R programme, the WSD successfully lowered the annual volume of freshwater lost from the government mains from 218 million m^3 in 2007 to 145 million m^3 in 2015 (a drop of 33%). This amounted to approximately 73 million m^3 in freshwater savings, indicating that the WSD has already made significant progress towards its 2008 TWM objective, already achieving 85% of the savings targeted for 2030.

The R&R programme is ongoing, with work on Hong Kong Island expected to continue through December 2017. Subcontracted work initiated in the last four years remains incomplete.[206] Though it continues to be unclear how the government plans to address leakage looking forward, the government has pledged to review the R&R programme when it is completed.[207]

Repair work has been complicated (Box 14) . Hong Kong lacks underground service tunnels, such as can be found in New York City, which has increased the complexity of even basic repairs, requiring coordination between numerous departments and bureaux, as well as disrupting traffic, commuters and impacting nearby businesses and residents.

BOX 14

Hong Kong's Topography Increasing the Risk of Leakage

Sources: AC, 2010

The WSD maintains average water pressure at 3-4 times more than its minimum target ensuring that it reaches consumers atop Hong Kong's tallest structures and located on higher ground. Besides higher energy costs, elevated water pressure increases:

- water loss from burst and leaking water mains, especially during low demand at night;
- high volume, rapid water outflow from taps and showerheads;
- suspensions of the water supply from bursts and leaks; and
- maintenance and replacement costs of water mains.

A further impediment to the rapid completion of even routine tasks is the necessity of resurfacing the sites of repair work. In 2009 alone, the WSD and its contractors were required to backfill and effectively rebuild 9,954 sections of road and pavement.[208] Even superficially, this appears a laborious procedure. Doubly so, as the Highways Department (HyD) found 1,284 (13%) instances that required reworking[209].

3.3.5 Water Theft: Unexpected Levels of Criminality

Under the Water Ordinance, "Any person who wastes or misuses, or causes or permits to be wasted or misused, a supply shall be guilty of an offence."[210] Additionally, anyone who "deposits, or causes or permits to be deposited, any solid or liquid matter in such a manner or place that it may fall or be washed or carried into water forming part of the waterworks shall be guilty of an offence."

The WSD employed just 13 people to monitor unlawful water activities, but now caters for 2.9 million accounts

Nevertheless, the WSD only employed 13 people in its Prosecution Unit (PU), as of December 2011, suggesting that the issue has been a low priority.[211] Furthermore, the members of the unit received minimal training,[212] indicated by the AC's concerns voiced in 2012 that it "may not be sufficient to equip its staff with the necessary knowledge for handling suspected unlawful water-taking cases."[213] The WSD provides for over 2.9 million accounts, whilst the PU had only six Customer Services Inspectors, as of the latest figures available.[214]

Water diversion for unauthorised purposes has been a persistent issue. In 1996, the EMSD reported that 12,000 water cooling towers had been installed across Hong Kong and were responsible for withdrawals of approximately 7 million m^3 per year. However, the WSD had only approved 116. Of those operational, 14% had been improperly installed, and 47% were not well maintained. Restaurants, retailers and industrial units were revealed to be behind most illegal installations. Between 2001 and 2005, EMSD conducted a follow-up survey, discovering 10,700 such cooling towers remained (Box 15).

BOX 15

The Water Cooling Trade Off: Saving Electricity & GHG Gases, Sacrificing water

Source: Electrical and Mechanical Services Department, 2015

In seeking to save energy, the Hong Kong government has been interested in wide scale deployment of water-cooled air-conditioning systems (WACS) technology for over 20 years, investing at least HK$29.7 million to research the technology between 1998 and 2007.

Data from 2015 indicated that more than a fifth of Hong Kong's electricity is dedicated to 'space' conditioning, with approximately 21% of domestic electricity and 26% of commercial power being consumed by air-conditioning.

WACS reportedly consumes 20-30% less electricity than the more commonplace Air-cooled air-conditioning systems (AACS), as well as operating more quietly. Since 2001, the government has been actively promoting its 'Fresh Water Cooling Towers Scheme' (FWCT Scheme), encouraging the adoption of WACS, to replace AACs.

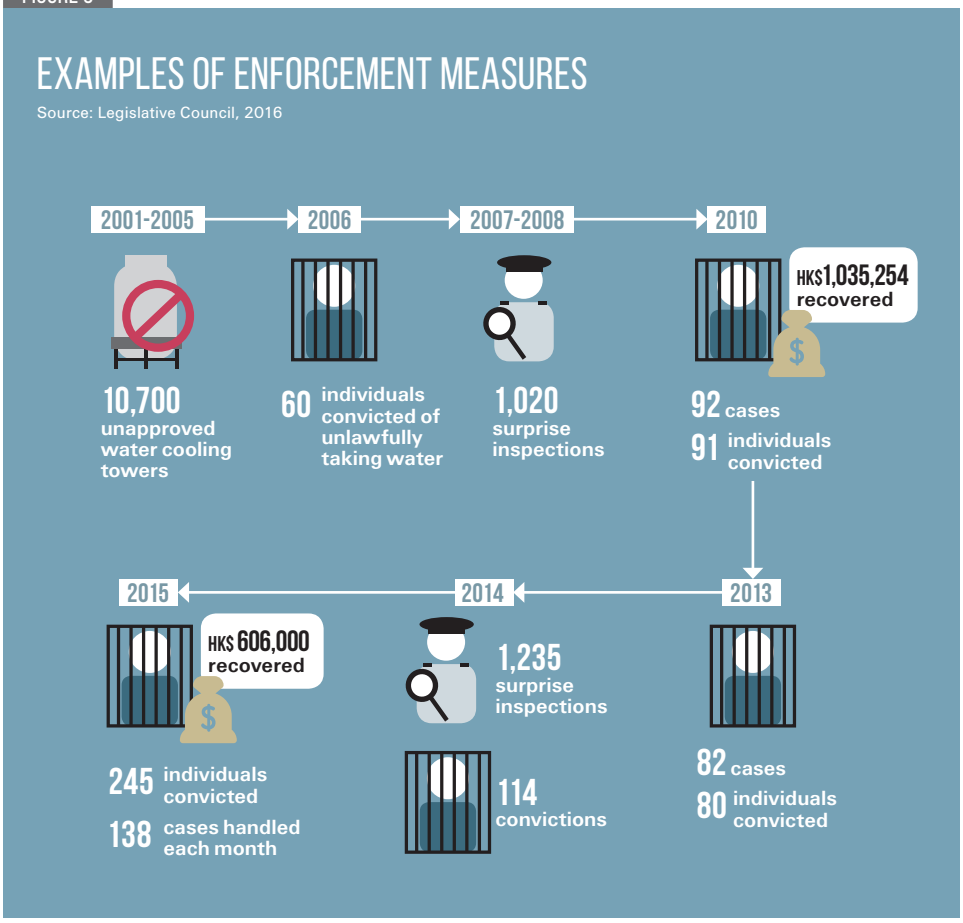
However, these systems require a large quantity of water. The Acting Secretary for Works, in 1999, told LegCo that the scheme would require approximately 100 million m^3 of freshwater per year – equivalent to 10.2% of Hong Kong's present annual freshwater consumption. The Director of Water Supplies at the time speculated that freshwater demand from WACS would rise from 21.8 million m^3 to 108.1 million m^3 between 2000 and 2014.

At present, WACS consume a relatively small volume of freshwater in Hong Kong. However, as the technology matures and becomes more attractive for large-scale space conditioning, potentially at the district-scale, the volume of water required for WACS is likely to grow exponentially. Reclaimed water is a highly viable alternative to the near-potable water currently utilised in this process.

The PU has long struggled with enforcement,[215, 216] lacking a large team of investigatory or prosecutorial staff. In 2013, the unit pursued just 82 cases of illegal use of water, convicting 80[217]. That same year, the PU was reportedly "strengthened"[218,219] and by 2014, approximately 1-in-10 surprise inspections led to successful prosecutions.[220] The PU reportedly began handling 138 cases per month in 2015, successfully prosecuting 245 individuals. However, they only succeeded in extracting fines amounting to HK$606,000[221].

Despite these and other successes (Figure 9), the PU still embodies many of the insufficiencies and inefficacies of the entire WSD. It appears to lack the funding and sufficiently experienced personnel it requires to become an effective branch. By failing to strengthen the prosecutorial arm of the WSD, the government is allowing offenders to illegally withdraw valuable water from the system, with no realistic expectation of being apprehended and held to account.

FIGURE 9

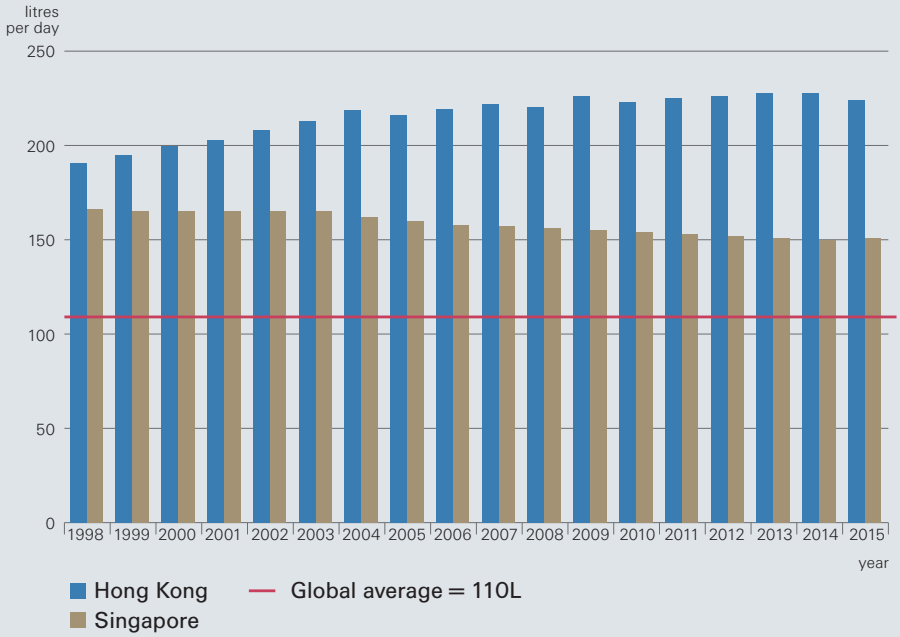


3.4 Reckless Overconsumption

The Office of the United Nations High Commissioner for Human Rights stipulates that governments should provide everyone with "sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses." The World Health Organization considers 50-100 litres per person per day would allow for the most basic needs to be met and minimise health concerns,[222] which contrasts with the 132 litres of freshwater consumed domestically per day in Hong Kong.[223]

CHART 8

DAILY PER CAPITA DOMESTIC CONSUMPTION IN HONG KONG AND SINGAPORE (1998-2015)



Note: It is unclear if non-revenue water is considered in Singapore's per capita data, however, 5-6% of water was consistetly unaccounted for between 1998-2015.

Domestic water consumption in Hong Kong is double that of Shanghai

Hong Kong's consumption contrasts unfavourably with other cities around the world (Chart 8). In Shanghai, for instance, daily domestic water consumption is approximately 106 litres per capita[224] – 20% lower. However, it should be noted that local consumption would be even higher, without seawater supplementing flushing water consumption. Indeed, if this were not the case, Hong Kong residents would consume up to 224 litres of freshwater every day[225].

In 2016, the OECD published findings from a global survey documenting water governance in 48 major cities[226], Hong Kong was one of the highest water users, as well as among the few cities in which domestic water consumption had increased since 1990.

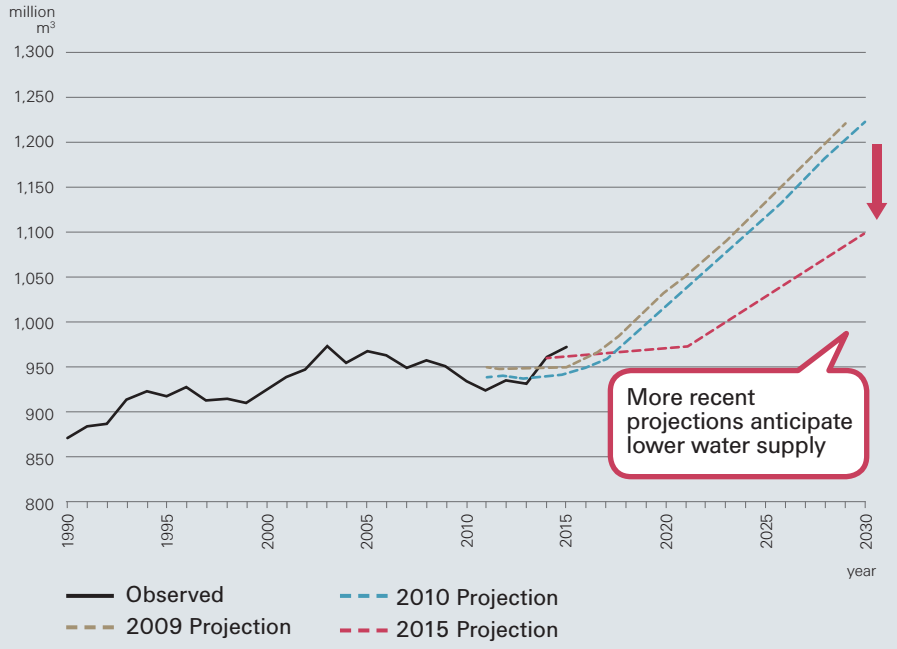
Of 48 international cities, Hong Kong is one of the few to have increased its consumption since 1990

Looking to the future (Chart 9), the government estimates that Hong Kong's water consumption will continue to rise, despite its TWM Strategy. Population growth is expected to play a key role in increasing demand, but the reasons behind the government's projected rise in per capita consumption remain unclear.

CHART 9

OBSERVED AND PROJECTED TOTAL ANNUAL FRESHWATER SUPPLY

Source: ADMCF, based on WSD, 2013; AC, 2015; Census & Statistics Department, 2007-2015



The WSD projects Hong Kong will need to supply 8 million residents with 1.1 billion m^3 of freshwater by 2030

In 2008, the WSD projected that it would supply more than 1.3 billion m^3 by 2030[227]. In 2014/15, the estimate was revised downwards to 1.1 billion m^3 [228]. This is still an increase of 13% over the next 14 years to meet the needs of potentially eight million residents[229]. The TWM Strategy is pivotal to the government's aspiration of capping water supply at 1.1 billion m^3, though the increased deployment of water-intensive technologies, such as water-cooled air conditioning systems (Box 15), may also complicate conservation efforts.

While in 2008 the government indicated that increases in water demand are to an extent offset by reduction in leakage[230], it is unclear how the unexpected rise in water loss from sources other than the government mains will impact demand projections and thus its future water management strategy.

3.5 Lack Of Rational Pricing

Some view water as the world's most underappreciated and undervalued resource. In Hong Kong, this view is substantiated by the low pricing structure, waste and overconsumption.

Globally, varied approaches to tariffs are employed including fixed charges, uniform volumetric charges and either increasing or decreasing block tariffs. The primary objectives include enabling stable cost-recovery of the supply and allocating scarce water resources appropriately, through fostering economic efficiencies while being both equitable and affordable.[231,232]

3.5.1 Paying for Hong Kong's "Precious Resource"

Tariffs for Domestic Consumers

All households in Hong Kong receive 12,000 litres of water for free every four months

Hong Kong's domestic freshwater tariffs are based on a volumetric block system[233], and are heavily subsidised (Table 3). The system permits every household account (approximately

Non-flushing, potable freshwater provided freely to every individual every 4 months is enough to fill around

20 bathtubs

TABLE 3

Water Tariffs and Consumption in 2013/14

Source: AC, 2015

	Water tariff (HK$/m³)
Domestic Water Supplies	
First Tier (first 12m³)	Free
Second Tier (next 31m³)	4.16
Third Tier (next 19m³)	6.45
Fourth Tier (remaining)	9.05
Non-domestic Water Supplies	
General trade purposes	4.58
Non-ocean-going vessels	4.58
Construction purposes	7.11
Ocean-going vessels	10.93
Flushing Water Supplies	
Seawater for flushing	Free
Freshwater for flushing – first 30m³ in a four-month period	Free
Freshwater for flushing – exceeding 30m³ in a four-month period	4.58

2.9 individuals) a free allotment of 12 m^3 (12,000 litres) of non-flushing potable water per four-month period (Figure 10). This equates to 122 litres per capita per day or slightly below the average of 132 litres per capita per day of freshwater used in Hong Kong. The average subsidised cost per person for this nearly full free allotment of drinking water amounts to HK$3.0 per m^3, or less than a fifth of the full production cost.

After exceeding the allotted 12 m^3, households pay a subsidised rate of HK$4.16 per m^3 (Box 16). This second-tier rate is maintained, until a household has consumed more than 43 m^3 (43,000 litres) – equivalent to 215 bathtubs over four months.[234]

Seventy percent of domestic water consumed in Hong Kong is subsidised

It is only after 62 m^3 of freshwater has been consumed (about 310 bathtubs) that the WSD deploys its so-called "punitive" rate, of HK$9.05 per m^3. If the punitive rate, which the government has indicated is set at 40% above cost-recovery[235], was based on the most recent figures (Box 16), the rate for the fourth tier of the domestic tariff system would be HK$21.98. That is more than double the present highest charges for both domestic (HK$9.05) and non-domestic consumers (HK$10.93 for ocean-going sea vessels). These costs are presently absorbed by the WSD and the General Revenue (see Section 3.5.2).

BOX 16

Setting a Cost-Recovery Rate

Source: AC, 2015

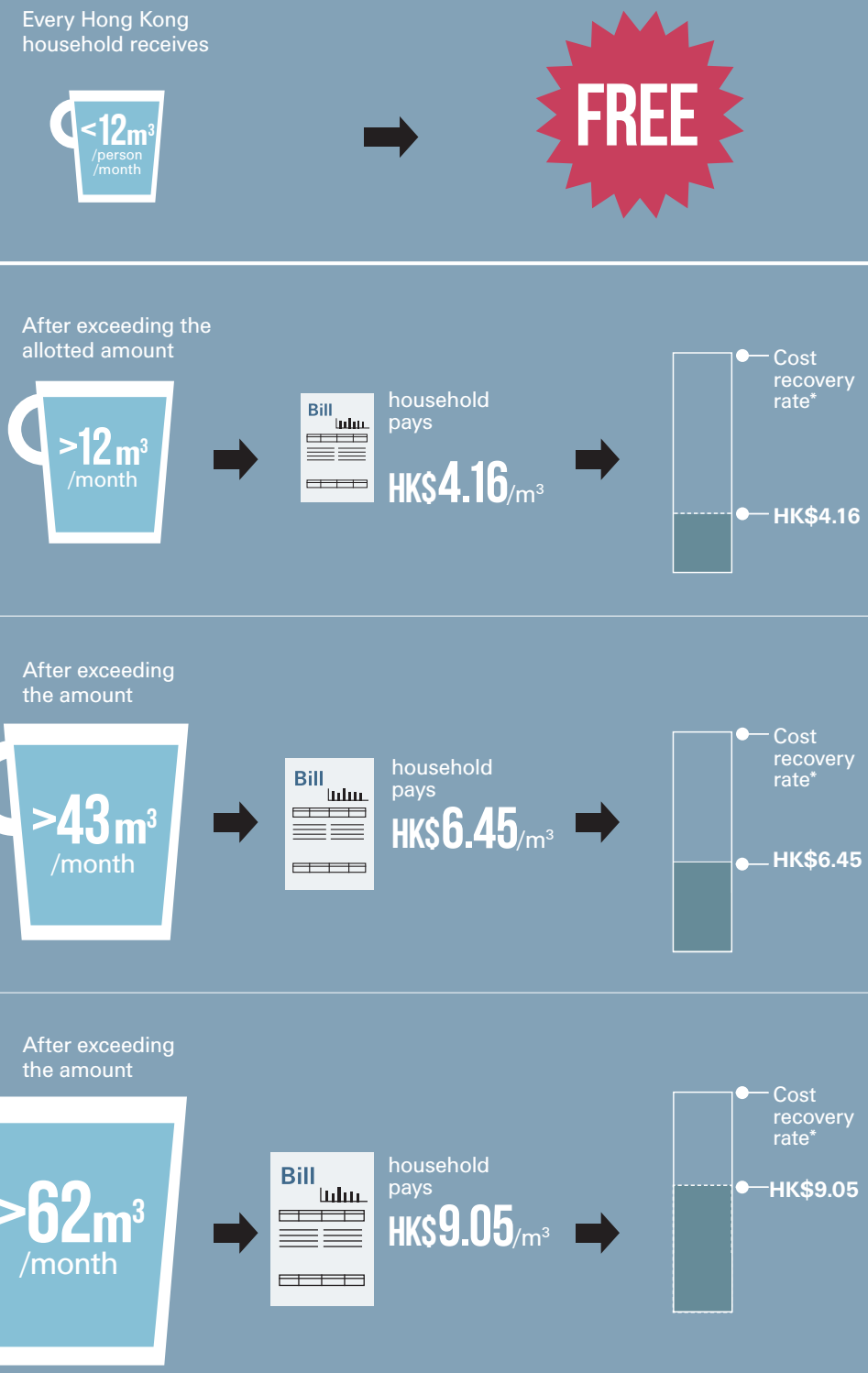
The 'cost-recovery rate' refers to the threshold at which production costs are covered.

Hong Kong has not altered its charge since 1996, when the HK$4.16 charge for Tier 2 was suitable for recovering costs. However, this rate covers just a quarter of the current full production cost per unit of freshwater, which had risen to HK$15.7 by 2016.

Overall, 70% of the water consumed is purchased at a government-subsidised price (Figure 10), making Hong Kong's pricing one of the cheapest in the developed world (Chart 10).

FIGURE10

HONG KONG'S WATER TARIFF STRUCTURE: DOMESTIC CONSUMERS

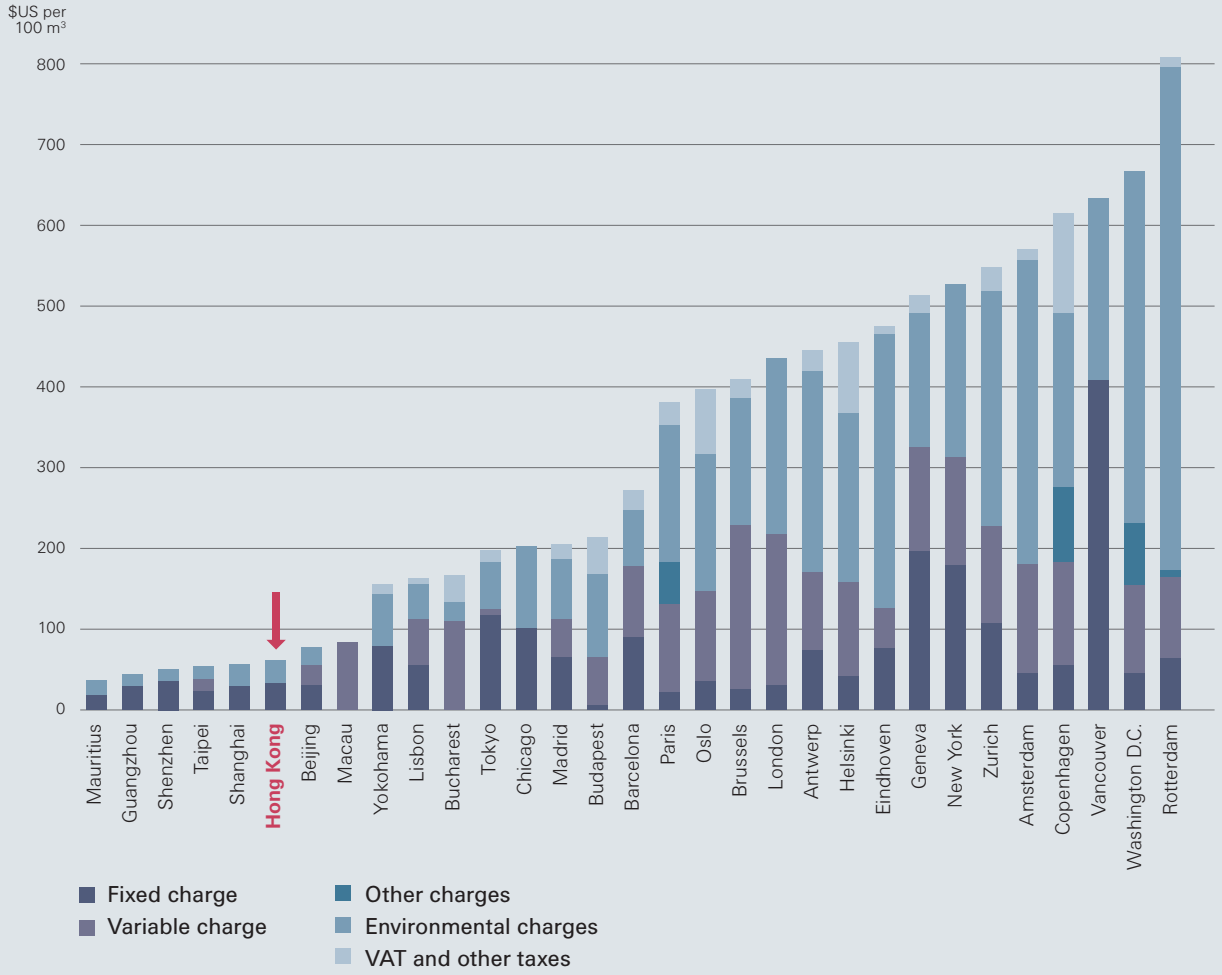


*Full production cost has increased to HK$15.7 per m³.

CHART 10

TOTAL CHARGES FOR WATER ACROSS GLOBAL CITIES IN 2015, FOR CONSUMPTION OF 100 M^3

Source: ADMCF, based on data from International Water Association, 2016



General trade consumes majority of non-domestic water, while paying less than the cost-recovery rate

Tariffs for Non-domestic Consumers

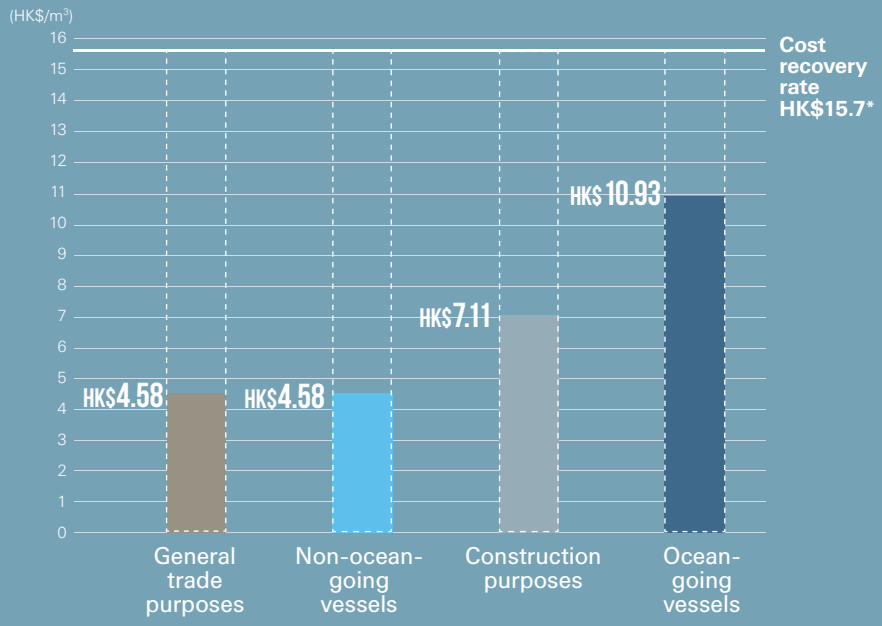
Non-domestic water consumers pay flat rates, based upon the "purpose of the supply" (Chart 11).[236] They are billed, as with domestic users, based on meter readings approximately every 121 days (around four months), although heavy water consumers are billed more frequently – on a monthly basis.

General trades[237] pay a tariff 10% higher than the second tier of the domestic rate. Whereas construction companies pay an elevated price, HK$0.66 above the rate charged in the third domestic tier.

CHART 11

TARIFFS FOR NON-DOMESTIC CONSUMERS

Source: ADMCF, based on data from AC, 2015



*Full production cost has increased to HK$15.7 per m³.

Foreign sea vessels pay a "punitive" charge of HK$10.93 – more than double the charge to trades, and HK$1.88 per m³ higher than the highest domestic tariff. It is expressly intended to "discourage shipping liners from taking on water in Hong Kong.[238]"

Delivering seawater to Sheung Shui or Fanling is twice as expensive as supplying freshwater

Flushing Water

Notably, Hong Kong's pricing does not end with potable water – the same applies to freshwater for flushing (Box 17). Seawater for flushing is also provided for no charge, but it is not a free resource. An economic assessment undertaken by the WSD in 2012 found that providing seawater to Sheung Shui or Fanling cost HK$10.4 per m³, which is almost double the cost of providing the same towns with freshwater, at HK$5.6 per m³.[239]

The WSD determined that 'reclaimed water' was optimal for flushing, costing just HK$3.8 per m³. Despite this, seawater is provided for free and toilet flushing is exempt from sewage charges, under the Sewage Services Ordinance.[240] This has resulted in Hong Kong residents again being disinclined to conserve a seemingly infinite resource.

Seawater is provided for free, despite requiring energy-intensive filtration, treatment and pumping

Seawater's chief benefit is that it is a vast, effectively renewable resource. Being readily available across a largely coastal Hong Kong, it is also less intensive on the electricity grid. In its 2014/15 annual report, the WSD stated that seawater filtration, treatment[241] and pumping consume 0.387 kWh/m^3, whilst raw and freshwater required 0.581 kWh/m^3 [242,243]. Nevertheless, considering advancements in low volume flush toilets, focusing attention on seawater for flushing will have reduced benefits overall.

BOX 17

Not So Flush – The True Cost of Flushing Water

Sources: WSD, 2013; 2015; 2016; 2017; AC, 2015; Research Office, 2015; Government of the Hong Kong SAR, 2015

Approximately 7.9% of Hong Kong's freshwater literally went down the toilet in 2015. Around 15% of Hong Kong households currently use freshwater for flushing, receiving the first 30,000 litres (30 m^3) for free, for a period of four months. This is over and above the 12 m^3 allocated for other domestic uses. A charge of just HK$4.58 per m^3 is levied for any additional water used for flushing. Further, individual household consumption is not monitored. The WSD averages water use figures based on aggregate data collected by a single meter installed in each building, regardless of the number of apartments. The cost is distributed evenly between all the accounts in the block.

On average, 92 litres of free freshwater is used every day by the 1.45 million Hong Kong residents not yet connected to the seawater flushing system, purely for flushing their toilet. Combined with the quantity of potable freshwater freely provided, these residents may receive 224 litres of freshwater every day.

The WSD converted a further 5% of users to seawater flushing with the completion of the HK$996.4 million 'New Territories Northwest Salt Water Flushing Supply Scheme' in March 2015. The plant meets the demands of 700,000 residents across Yuen Long, Tin Shui Wai, and part of Tuen Mun. It was estimated that the facility would save 21 million m^3 of freshwater per year. A similar facility in Tung Chung is planned and estates within Pok Fu Lam have also been included in this scheme.

3.5.2 A Persistent Deficit

Hong Kong's water tariffs were set to recover production cost and achieve a target return on the 'Average Net Fixed Assets' (ANFA).[244] Over a period of 20 years, this has never been achieved. In 2015, the AC stated that:

> "Since 1996, water charges have not been revised and the Waterworks Operating Accounts reported a deficit each year from 1998-99 to 2013-14. Accordingly, the waterworks operation achieved negative returns on ANFA during the period. Notwithstanding such negative returns, the Government continued to adopt positive target rates of return on ANFA of 6.5% from 1998-99 to 2011-12 and 3.4% from 2012-13 to 2013-14."[245]

The full cost of freshwater is ultimately covered by tax dollars

The annual deficits run by the WSD effectively mean that the department is subsidised every year and the full cost of this water is ultimately covered by tax dollars via:[246]

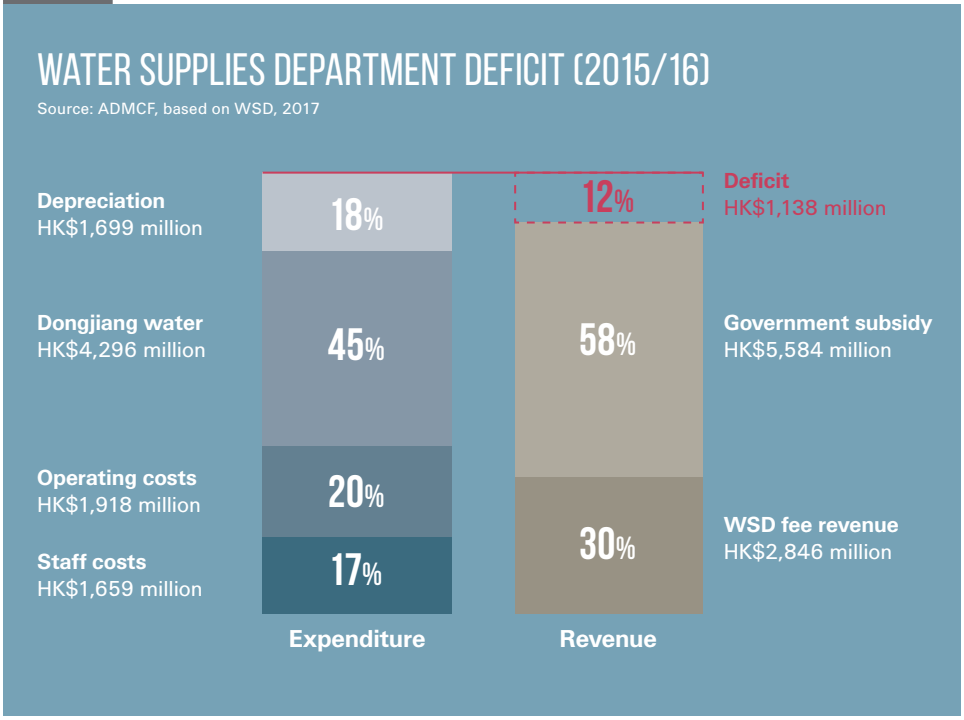
- Direct subsidies: the government is subsidising the WSD for the loss of revenue from maintaining artificially low tariffs; and
- Deficit transfer: despite government subsidies, the WSD's revenues do not match its expenditures. However, since the WSD is not a separate legal entity, its deficit belongs to the general government deficit and is therefore meant to be financed by the General Revenue.

The WSD has been unable to cover operational costs for 20 years

In 2015/16, direct subsidies represented HK$5.58 billion (58% of the WSD's expenditures) whilst the deficit stood at HK$1.138 billion (12% of the same amount) (see Chart 12).

The deficit has been further exacerbated by the escalating expense of producing freshwater. The AC determined that the full unit production cost of freshwater (including the Dongjiang supply and that sourced from Hong Kong catchments) had, as noted above, climbed to HK$15.7 by 2016[247].

CHART 12



If it were better positioned to cover its overheads, the WSD might be able to assure users that payments would be contributing to expanding and developing the department's services and infrastructure.

An alternate perspective is that by keeping the WSD in a perpetual state of deficit, the government has pushed the water authority to continually strive for cost-effectiveness and operational efficiency. However, given the inefficiencies identified, this does not seem to be the case.[248,249]

In theory, by removing the need to generate revenue (through higher charges) the department has been free to forgo profit in the pursuit of conservation. Again, this has not materialised.

3.5.3 An Ambiguous Policy and Lack of Proper Pricing

The government has priced water to protect the growing number of disadvantaged citizens

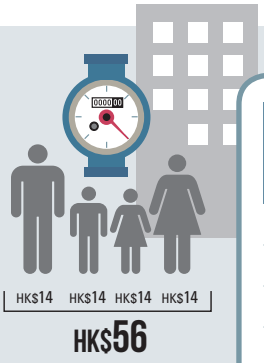
The rationale for the present tiered tariff system was not simply to recover costs, but also to provide progressive pricing, which discouraged overuse, while largely insulating Hong Kong's growing number of disadvantaged citizens from the threat of exorbitant charges.

BOX 18

Water Allowances Under the CSSA

Source: Social Welfare Department, 2016

Amount of allowance depends on the number of persons sharing the water meter



Number of persons sharing the water meter	Allowance per month (HK$)
1	Nil
2	8.7
3	12.0
4	14.0
5	16.2
6	18.2
7	20.2
8	21.8
9	22.9
10	23.9

The government additionally provides a water and sewage charge allowance for those who struggle to make ends meet, under the Comprehensive Social Security System (CSSA) (Box 18).[250]

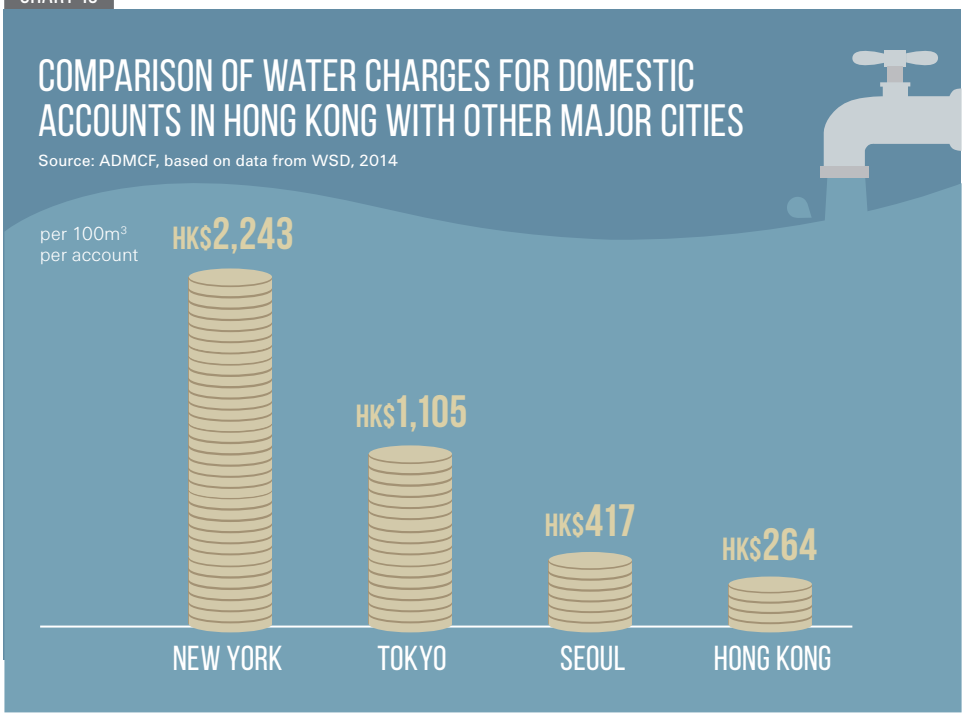
Low tariffs and allowances have thus proven largely effective in shielding those on lower incomes, but the tariff system has also benefited the members of Hong Kong's community who can well afford to pay a price that reflects the 'true' cost of water.

Free allotments and frozen tariffs benefit both the impoverished and the wealthy, discouraging conservation

The frozen tariffs, combined with free allotments for all domestic users, have created a false sense of security amongst Hong Kong's public who can afford to pay, that water is plentiful and its conservation is not a concern. This is despite the fact that local supply is insufficient to meet even a quarter of current demands and that the government only meets the majority of demand by paying a relatively high price for water from China. The lack of awareness has frustrated attempts at curbing consumption.

Regarding the current price level, comparison with other cities is instructive (Chart 13). Indeed, a comparison with Guangzhou's tariff system demonstrates the shortcomings of Hong Kong's (Table 1). Hong Kong is exceptional for having a universal free allotment, and the progressive strategy employed by Guangzhou has ensured that a disincentivising charge is incurred for those consuming more than their recommended allotment.

CHART 13



Whilst the United Nations Development Programme (UNDP) recommends that expenditures on water should not exceed 3% of a household's income,[251] it emphasises the need to protect water sources and minimise wastage. For Hong Kong's 2.9 million domestic accounts, the average water charge in 2015-16 (including those not required to pay any charge) was HK$48 per month and amounts to about 0.3% of the average monthly household expenditure.[252] In 2016, 1.48 million households in Hong Kong earned a monthly income of HK$20,000 or more.[253] Based upon this, a large proportion of Hong Kong likely dedicated less than 1% of their monthly household budgets to water bills.

In line with the UNDP, the Chinese government recommends pricing water at 2.5% to 3% of household income[254], ten times Hong Kong's current ratio. Shenzhen is considering an 8.95% price increase, proposed in 2015, meaning top tier domestic users would pay HK$8.72 (RMB 7.5) per m^3.[255]

The Chinese government recommends pricing water at a much higher rate than Hong Kong

In 1996, one year after the start of the current pricing scheme, the average Hong Kong household had 3.3 persons, or about 15% above the current size, which the Census & Statistics Department (C&SD) projects will fall further to 2.7 in 15 years. Smaller households also have lower efficiency in per capita water use, which puts indirect pressure on water resources.[256]

Since being set in 1995, water prices should have doubled solely on the basis of Hong Kong's annual inflation. If Hong Kong had an average of 3.5% per-year inflation for 20 years, then water prices should have increased by another 15%, just on the basis of decreasing household size. In contrast to static retail prices during this time, the wholesale price of water from the Dongjiang water more than doubled from HK$2.2 per m^3 in 1995 to HK$4.6 per m^3 in 2013 and then surged further, to HK$5.1, after renegotiation in 2015. Further, the Tier 3 tariff, supposedly designed to recover costs, covers just 41% of the now HK$15.7 required to produce each unit of freshwater[257].

3.5.4 Requests for Increased Tariffs Blocked

Supported by LegCo, Hong Kong's water tariffs have been frozen since 1995

In 1996, the government proposed increasing the domestic tariff by 8.5% and the non-domestic tariff by 9.3%.[258] LegCo dismissed the proposal. In 1999, it approached LegCo again, attempting to raise the water tariff by 5%. The panel refused the proposal "on the grounds that the economy at that time had not recovered" from the 1997 Asian financial crisis.

In its 1998-1999 annual report, the WSD acknowledged the "financial impact on domestic users, as well as public views" of price revisions.[259] However, it stated that the "water charges do not fully reflect the cost of production," and noted the "high level of government subsidy through contribution from rates." In its latest 2015/16 report, these conditions, which have remained unchanged, were omitted, and the WSD stated it was committed to providing services as cost-effectively as possible," assuring the general public that it would "exercise strict financial discipline."[260]

According to the WSD's annual reports, the department sought to reform the water tariffs from 1995-96 until 2003-04. Since 2004-05, however, such reform has not been mentioned, suggesting that it is not on the government's current agenda.[261] According to the WSD's latest annual report (2015/16), "The Government continues to review the water tariff periodically, taking into consideration a number of factors, including affordability, financial performance of waterworks operations, the prevailing economic situation and the views of Legislative Council members."

Raising tariffs is undoubtedly politically sensitive, especially in relation to such an essential resource such as water. However, LegCo has permitted DSD to revise its charges in 2007[262,263] with a view to allowing the department to attain cost-recovery via incremental schemes (Box 19).

BOX 19

Attempting to Recover Costs

Source: AC, 2013

In 2008, the Sewage Charge was revised at a rate of 9.3% per annum. By 2015-16, the charge had more than doubled from HK$1.2 per m^3 to HK$2.44 per m^3, and is set to rise to HK$2.92 by 2017-18.

The Trade Effluent Surcharge (TES) was also revised in 2008 for 13 different trades with a variety of rates. By 2013-14, TES charges alone allowed the DSD to recover 69.1% of its operational expenditures.

Since the DSD has been able to revise its charges, this raises the question of why the WSD should not be given similar consideration in a bid to improve its cost-recovery rate. If Hong Kong residents and enterprises have proven prepared to absorb growing costs for the disposing of their wastewater, it seems reasonable to expect consumers (who can afford it) to pay an appropriate fee for the water they use.

3.5.5 Price Elasticity of Water

In addition to recovering costs, tariff reform should be considered as a means of improving water conservation

Having a 'cost recovery' or 'cost plus' tariff, would ideally encourage appropriate attitudes and behaviour towards water consumption as well as providing the financial resources for the government to improve the integrity of the water system in a sustainable manner.

Consumers have been too well insulated from the impacts of the rising costs of the Dongjiang supply

Thus, an important reason for reforming Hong Kong's current pricing structure would to be improving water conservation. Consumer awareness would likely follow a tariff increase, as the rate change impacted household budgets. The government has repeatedly referred to water as a "precious natural resource,"[264] yet it has been unsuccessful in persuading consumers that conserving water is imperative. Users have been too well-insulated from the impacts of the rising costs of the Dongjiang supply, and this lack of awareness has bred complacency.

Research in other jurisdictions indicates that the price of residential water is relatively inelastic.[265,266] Some experts have indicated that particularly for the wealthy, price increases simply do not discourage overconsumption.[267]

It could be argued that the price elasticity of water consumption in an urban setting like Hong Kong is lower than in countries where a much larger share of water goes to discretionary uses, such as watering lawns. Nevertheless, if water-saving devices for taps, showerheads and appliances are readily available, consumers will have an incentive to buy and use them if water prices are elevated. This, however, does not necessarily excuse the free allocations of water provided in Hong Kong for those who can afford to pay.

4 TOWARD A WATER SECURE FUTURE

Previous sections of this report highlight a range of issues and challenges that raise questions as to Hong Kong's long-term strategy in ensuring a secure supply of water to its residents.

Hong Kong must take a holistic and forward-looking approach that considers water security at the regional-scale

Hong Kong must take a holistic and forward-looking approach that addresses issues such as climate risk, energy use, leakage and regional competition for resources, as it moves toward sustainable water management in the PRD. It must consider not only its water security, but also that of its neighbours in the PRD, which also rely on the Dongjiang for much of their freshwater supply.

Clearly there are several relatively simple and effective approaches that would be quick to implement. However, it remains critical that any water strategy bolsters long-term resilience ahead of increasingly severe and frequent shortages expected as our climate changes.

Many of the challenges faced by Hong Kong's water managers need to be tackled at the macro-scale, directed by clear targets and deadlines but, ultimately, any policy should promote action at all levels, from individual to regional, providing realistic pathways for achieving all goals on schedule.

Toward resolving the challenges recognised, key considerations are identified that can be broadly grouped into the following areas:

Rethinking governance and establishing long-term water policy to ensure safe and secure water supplies from source to tap, not just to the point of connection.

Improving departmental performance by setting clear and timely goals and clarifying/enforcing penalties for underperformance and non-compliance.

Effective supply-side management to minimise water loss across both public and private sectors and expand/explore other taps.

Efficient demand-side management that identifies innovative solutions to stem overconsumption and move Hong Kong towards sustainable use.

Tariff reform to provide a fair and equitable mechanism for pricing a precious resource.

4.1 Rethinking Governance and Establishing Long-Term Water Policy

4.1.1 Getting the Basics Right: Establishing a Comprehensive 'Source to Tap' Policy

As noted, quality control and an uninterrupted supply have long been the WSD's top priorities, and its focus as reflected in its Mission, has thus far been to provide good quality drinking water to Hong Kong residents 24/7. Whilst this is indeed a primary objective, the Administration needs a comprehensive water policy that is responsive to regional socio-economic and environmental realities, such as the increasing importance of climate change and changing regional dynamics.

The engineering mind-set of the DevB has undoubtedly benefited Hong Kong, as infrastructure has expanded to satisfy demand. However, neither the WSD nor the DevB have cultivated socio-economic or environmental expertise (i.e. economy, ecology) to the same standard as their engineering prowess. If water security is to be successfully addressed, policymaking on water must be enhanced.

Importantly, Hong Kong needs to redefine the importance of water which is still perceived as an abundant resource by the community at large. The government as a whole does not appear to consider water as a strategic resource that is an important aspect of regional security, as for example China's central government does. Singapore has also focused on "the sustainability of clean water supply", as well as welcoming private sector investment and engagement, and ensuring that water security is never far from the mind of its leaders.[268]

Such an approach means considering and defining social goals. The UN notably identifies the following development outcomes that water goals and targets should aspire to: healthy people, increased prosperity, equitable societies, protected ecosystems and resilient communities. These goals may provide a useful directive for Hong Kong in developing a comprehensive water policy.

The WSD should establish policy in line with its 2006 pledge, to ensure integrity of water supply from source all the way to tap

Policy commitments should further be made, such as affirming and mandating the WSD's 2006 pledge to implement "measures and practices to ensure the quality and safety of drinking water to consumers beyond the connection points."[269] This means providing for policy and regulations that enhance the integrity of the entire water system and reduce the potential for leakage, including on private premises. Innumerable cities around the world, such as the UK[270], Canada[271] and Singapore[272], have already embraced this approach. Hong Kong currently lags behind comparably developed cities and needs to raise itself, at minimum, to the same standards.

4.1.2 Un-silo Governance and Reconcile Multiple and Overlapping Responsibilities

Departmental jurisdictions and responsibilities should be claried and clearly delineated

Fundamentally, governance reform is essential to ensuring the management of Hong Kong's water resources is unified under a policy making body that has the skills, expertise and authority to develop and implement a comprehensive water policy as outlined above. Effective governance of the water sector, as one integrated policy area, thus needs substantial reform, not improvements at the margin. A look at other jurisdictions, such as Singapore, is instructive (Box 20).

Hong Kong should thus be striving for a more integrated approach to water management, with department-level roles being more clearly delineated. The lack of clarity surrounding the jurisdictions and responsibilities of various departments has had adverse consequences for safety, water quality and management.

BOX 20

Singapore's Water Governance

In Singapore, water resource management is the responsibility of the Ministry of the Environment and Water Resources (MEWR) under which are two statutory boards:

- The PUB, the national water agency tasked with managing the city's water resources; and
- National Environment Agency (NEA), charged with sustaining a "clean and green environment."

In March 2016, a delegation of LegCo's Panel on Development visited Singapore's water authorities on a study mission. They observed a "clear division of responsibility of the PUB and NEA," noting that the Singapore water management system "enables a holistic and integrated approach to protecting and planning of water resources, while building in effective checks and balances in the regulatory regime for the quality of drinking water."

The LegCo Panel on Development's delegation similarly noted, that unlike Singapore, Hong Kong lacks an authority that is independent of the WSD, to monitor water quality from the perspectives of public health and the environment. In Singapore, this is a role fulfilled by NEA. The agency also has a technical advisory committee that includes overseas experts.

A new culture needs to be created with new positions dedicated to bringing in non-engineering perspectives, such as those outlined above.

Hong Kong could benefit from establishing an independent regulatory water board

As periodic audits[273] have been insufficient to improve the WSD's operations, the government may also consider some form of independent oversight, with the power to enforce, as well as to ensure action is taken to address shortcomings. There are numerous international examples of independent and semi-autonomous regulatory boards (Table 4).

A key goal of any such reform is to increase accountability. It is up to the government to investigate the most feasible approach, but until water security is explicitly considered in policy and relevant departments held to account, Hong Kong will continue to struggle to manage its water sustainably.

4.1.3 Seek a Sustainable Water Agreement with China that Encourages Conservation

The next three-year DongShen Agreement will be renegotiated by 2018. Hong Kong's representatives should take the opportunity to seek a water agreement that contributes to water security in the PRD and encourages conservation. The current mechanism – wherein Hong Kong advances three annual payments – means the WSD has little incentive to judiciously manage Hong Kong's water supply. Further, whilst local demand remains high but under the supply ceiling[274], there is minimal motivation for the WSD to introduce or enforce restrictions that could promote improved water conservation practices, but could make the department even less popular.

TABLE 4

International Examples of Fully and Semi Independent Regulatory Boards

Source: ADMCF, based on information from Little Hoover Commission, 2009; Rouse, 2013; The Utility Regulator, 2016; Superintendencia de Servicios Sanitarios, 2017; Lazaroms and Poos, 2004; Essential Services Commission, 2016

Board	City/State/ Nation	Membership	Responsibilities
State Water Resources Control Board (SWRCB)	California, USA 	Five full-time board members; four experts in relevant fields (i.e. engineering, water quality, policy, water rights), supported by additional staff	- Set state water policy - Set tariffs - Review actions of water authorities - Allocate financial assistance - Monitor and ensure high water quality and availability - Improve transparency and accountability - Ensure consistency across Water Boards
The Utility Regulator	Northern Ireland, UK 	Seven board members; the Chief Executive, a non-executive chairperson, three non-executive members, all with expertise in relevant fields, and with government representation, supported by additional staff	- Set tariffs (domestic and commercial) - Ensure utilities' compliance with relevant ordinances - Set efficiency targets - Encourage competition in market - Arbitrate complaints, disputes and appeals
Superentendencia de Services Sanitarios (SISS)	Chile 	Superintendent, with three immediate subordinates charged with overseeing transparency, communications, internal audits, and five divisions; leadership are all experts, with qualifications in engineering, civil administration, economics, etc.	- Set tariffs, in accordance with Ministry of Economy decrees - Grant concessions related to the freshwater supply and subsequent wastewater, in compliance with decrees issued by the Ministry of Public Works - Supervise providers' operations - Prosecutions - Ensure compliance with environmental ordinances
Decentralised water boards (ultimately coordinated by the Dutch Water Authorities)	The Netherlands 	Average of 30 members, an executive council and a general administrative body; representing households, landowners, tenants, building owners and industry	- Set/manage budgeting - Taxation on water resources (which provide funds for operation of the water board) - Manage licensing - Water management planning - Oversee quality control - Issue permits - Oversee sewage treatment operations
Essential Services Commission	Victoria, Australia 	One chairperson, as many commissioners as deemed necessary (currently two) and a CEO, supported by around 70 additional staff	- Regulate prices - Ensure efficiency targets are met and incentivised - Oversee financial status of industry - Ensure competitiveness within market - Ensure industry comply with health, safety and social legislation - Ensure local operations comply with nation regulations

Hong Kong government should seek a more flexible water agreement that would incentivise resource conservation

The Hong Kong government should seek a more flexible deal, such as Hong Kong retaining the 'right of first refusal,' decided on a predetermined basis. This would allow Hong Kong to import variable quantities of water to meet demand while avoiding the overcharging that takes place under the current 'take-or-pay' arrangement. But, most importantly, it would reduce water waste while increasing the incentive to safeguard resources via improving domestic water use efficiency, diversifying local water sources and motivating water conservation. However, the Guangdong Provincial government has a long-established reluctance to negotiate on this topic.

Only when Hong Kong better manages its own water resources, through an improved purchasing scheme, more representative pricing and increased savings, will there be mutual benefits for the entire PRD.

In practical terms, this means that in the event that Hong Kong's reservoirs are filled by local rainwater, the WSD should be able to take what it needs, without paying for the full allocation regardless.

A predictable rebuttal to any such a request is that interrupting the near-constant supply is untenable for technical reasons. However, every year, the supply from the Shenzhen reservoir to Hong Kong is suspended for maintenance in December.[275] This suggests that there is no technical requirement for maintaining a constant steady flow of water. At the local and regional scale, this is also a highly pragmatic approach, optimally reducing Hong Kong's demand on the Dongjiang and becoming an example for neighbouring urban centres.

In paying a relatively high price for the Dongjiang's water, Hong Kong could further push for allocation of some of its payments to the Guangdong provincial government's 'water resource fee' to facilitate protection of the watershed. Such a fee is charged for water withdrawal from natural water sources and is one component of the final water price charged to individuals, agricultural and industrial users. On 26 December 2016, the Guangdong government issued a document on how to implement such a mechanism within the province. This document also indicated that a 'water resource fee' could be a financial source for relevant eco-compensation programmes.[276]

Guangzhou and Jiangxi provincial governments signed the 'Agreement on the Upstream-downstream Eco-compensation along the Dongjiang River Basin' in late October 2016. Both provincial governments will contribute HK$1.16 billion (RMB 1 billion) every year. The initial phase of this agreement will run for 3 years, and the water quality at interprovincial sections is required to be at least Grade III.

4.2 Improving Departmental Performance

In order for the WSD to make progress, and address problems before they become crises, the department needs to shift from a risk-averse, reactive and operations-focused mind-set and embrace innovation and proactivity. Greater emphasis should be placed on multidisciplinary collaboration, with plans integrating benchmarking, performance-improvement measures, strategic planning and risk-based asset management.

4.2.1 Initiate Measures to Incentivise Improved Performance

As noted, the WSD has routinely come under fire from the likes of the AC and the Office of The Ombudsman, and has been the subject of extensive questioning from LegCo members. There is a clear case that the Department must improve its performance.

Innovative solutions should be encouraged to improve the WSD's performance

According to the WSD's most recent annual report, the department has been striving to establish "strong and effective communications channels between managers and staff", and to reward efficiency, productivity and new ideas. In addition, it could consider adopting more appropriate key performance indicators. Further improving leak response times and rewarding or remunerating units or staff who contribute to significant water savings could promote improved performance and conserve a valuable, finite resource.

It may also consider awards programmes. Macao Water, for example, has such a system to encourage innovation and creativity, specifically naming winners alongside their project's purpose in its annual report.[277] Adopting a similar approach may promote ingenuity within the department.

One approach to address poor performance is the practice of whistleblowing. However, Hong Kong's businesses and the government can fire employees for disclosing wrongdoing or incompetence, leaving the employee with no recourse and a tarnished reputation.[278] This has allowed complacency and for negligent habits to form and persist, since punishment for ineptitude is rare and often not punitive.

4.2.2 Crack Down on Illegality and Improve Prosecution Records

The WSD should seek to limit illegal activities through greater enforcement of the Waterworks Ordinance

Although there has been an improvement in the rate of prosecution, and successful convictions, there is certainly room for improvement in the department when enforcing the Water Ordinance and prosecuting offenders.

To improve buildings' inside service water quality, the WSD should make greater use of the Waterworks Ordinance to issue court orders and fine property managers. Ongoing fines should be made payable to tenants to

install and maintain water filters until the property managers have cleaned up their act. Comparable powers have been handed to the Joint Office of BD and FEHD, which handles seepage issues. The JO has the jurisdiction to fine convicted non-compliers up to HK$450 per day.[279]

In addition to increasing enforcement, the WSD may also consider 'naming and shaming' flagrant building violators by posting prominent notices in offending building lobbies.

BOX 21

Punitive Prosecution

Source: PUB, 2009; Legislative Council Secretariat, 2006

In seeking to eliminate unauthorised withdrawals and damage to pipelines, Singapore enforces strict legislation, whereby offenders face fines of up to HK$277,980 (S$50,000) and imprisonment for up to three years. Between 2005-2010, less than five cases of illegal siphoning were brought to court each year.

This markedly contrasts with the maximum penalties under Hong Kong's ordinance – a maximum fine of HK$25,000 and no jail time. Consequently, 91 consumers were convicted in Hong Kong for unauthorised withdrawals in 2010 alone.

Where public health and safety is threatened, contractors must be held fully accountable

The government should also adopt an expedited protocol for fining contractors responsible for endangering public health, such as in the 'lead-in-water' scandal. Culpable contractors should also be financially accountable for any and all remedial works, with penalties considering the costs of remunerating the government and any other parties until a safe delivery is ensured.

In addition to addressing the integrity of the supply, strict protocols must be enacted for identifying and prosecuting individuals who have made unauthorised connections to the mains or private pipelines (Box 21), as well as of those who illegally benefit from those connections[280]. Part of this can be achieved through improved inter-departmental communication, as other departments have a precedent of identifying and reporting infractions. The FEHD, for instance, monitors wet markets across Hong Kong and alerts the WSD to possible violations, such as water leakage issues. However, reporting has been insufficient, according to the AC.[281]

4.2.3 Address a Pattern of Inadequate Training

A major issue within the WSD is the pattern of inadequate training. Both meter readers and PU personnel are frontline staff with a high level of contact with the public. Allowing them to engage members of the public with inadequate training, as highlighted, has likely compounded the crisis of confidence as the department is associated with negative experiences and poor handling of problems. The WSD committed its 4,407 staff to 10,324 training days in 2015/16, amounting to a little under two and a half days of training if evenly distributed.[282]

An internal audit should be conducted by each unit within the WSD to identify areas of weakness and, following a review, rigorous induction and training programmes should be introduced. There is no reason all branches of the WSD should not continually reflect on and improve their operations through staff training.

Furthermore, programmes should be recommended for allied departments, such as the EPD and DSD, including education on the current and future water landscape of Hong Kong. Notably, the WSD indicated in its most recent annual report that it has a programme of "inter-departmental knowledge sharing sessions" – 'ENGINEER Talks' – through which staff are provided with specialist insights from current and retired colleagues from other departments.[283] Such programmes should also focus on interdepartmental collaboration, allowing staff from other departments to familiarise themselves with the varied responsibilities and charges of the WSD.

4.3 Effective Supply-Side Management

4.3.1 Addressing Non-Revenue Water: Plug Leaks in the System

While the WSD does not directly measure all means via which expensive, treated water is lost from the system[284], it pledged to LegCo that it would strive to do so in 2015[285,286]. A rigorous programme therefore needs to be established to account for previously unaccounted for water. Without this knowledge, it will continue to be extremely challenging for the WSD to identify and resolve such losses.

The Hong Kong government needs to address leakage from private premises

The government favourably compared itself to Taipei's leakage rate of 16.7% in 2014 when the WSD successfully reduced losses from the local mains to 16%.[287] However, this figure did not account for losses through illegal withdrawals, metering inaccuracy or leakage on private property – a further 15%.

In Denmark, an effective approach was adopted in 1989 to address the disparities between supply and consumption.[288] To motivate operational improvements (i.e. reducing leakage and addressing unauthorised water use), the Danish government began to tax its water distributors based on the water supplied at €1 per 1,000 litres. Penalties were levied on utilities failing to reduce non-revenue water to less than 10% of supply.[289] As a result, non-revenue water was rapidly reduced to below 10% throughout the country, with Copenhagen boasting 6.5% and certain decentralised networks achieving less than 1%.[290]

However, since the WSD is a public service provider, an alternate approach may be necessary. In Singapore for example, building managers or owners are financially accountable for the water lost between the point of connection (measured by a 'master meter') and household meters[291]. The accompanying penalties, accruing on every day the leakage persists, would likely motivate offending properties to rapidly address the issue. The government is already seeking to "strengthen urban fabric", addressing aging and failing infrastructure, through its 2030+ vision, however, water leakage is not explicitly mentioned.[292]

The five-year WIN is another initiative of the WSD which, in addition to ongoing conservation campaigns, could reduce the drawdown of Dongjiang water. Pilots of the WIN began in 2015[293], though the WSD has been encouraged to deploy the technology "as soon as practicable"[294]. The scheme will significantly improve the ability of the WSD to monitor, regulate and maintain the network.

Hong Kong has to balance its options, and consider if it can afford to continue wasting a third of its water

Any strategy combatting leakage, especially on private property, will undoubtedly cost millions of dollars; an expense that would most likely have to be absorbed by private building managers and owners, potentially aided by government subsidies. As challenging as it would be to economically justify rehabilitation[295], social and environmental factors, which are not easy to financially quantify, must be given equal consideration. The expense of repairing the system must be weighed against allowing hundreds of millions of cubic metres of an expensive, largely imported and "very precious resource"[296] to be lost and wasted[297]. This is not a problem that will simply go away, nor will it be addressed without firm guidance and leadership from the Administration.

4.3.2 Other Taps: Explore and Expand Local Sources

Taps that may provide additional water resources in Hong Kong at varying cost and feasibility include:

- Reclaiming water
- Harvesting rainwater
- Desalination
- Expanding and deepening existing reservoirs

Hong Kong could learn from Singapore's example and significantly expand its use of reclaimed water

Reclaiming Water

As the world faces increasing water stress, cities across the globe are seeking to develop future water management systems that offer resilience and sustainability through closing the water cycle.[298] This means that water used is maximally reclaimed, retreated and reused.

BOX 22

Singapore's NEWater

Source: LegCo, 2016

Singapore's Public Utilities Board (PUB) began to highly purify its reclaimed water, producing 'NEWater,' in 2003. It designated the approach as its "third National Tap," alongside harvesting rainwater and importing water from Malaysia. At present, four plants provide 30% of the small nation's water and is planned to account for 55% by 2060.

Singapore has developed its water strategy to enhance its resilience, ultimately aiming to achieve self-sufficiency (Box 22).[299] The principles of their plan include capturing every drop of used water and rain and recycling "endlessly."[300] The appeal of this approach is that the volume of wastewater, once generated, stays relatively constant (aside from the impacts of leakage and evaporation), reducing dependence on fluctuations of other sources brought about by seasonality, climate variability and competition.

Hong Kong's sewage water is generally treated before it is discharged into the sea, but is far from a potable standard. Reclaimed water is former wastewater that has been treated, with impurities, contaminants and solids removed. It can be used in a variety of ways, most commonly for irrigation, recharging groundwater aquifers and for industrial purposes. It can also be heavily filtered and purified to the point that it is suitable for human consumption (Box 23).

Regardless of the quality and types of 'reclaimed water', i.e. greywater, stormwater, the WSD has prohibited its use in six instances[301]. It may not be used for: human or animal consumption; bathing; filling swimming pools; preparing food; washing dishes; irrigating edible herbs, fruits or vegetables; and hot water services.

BOX 23

Drinkable Wastewater?

Source: LegCo, 2016

An assessment conducted by HKU determined that treating local effluent to a potable standard would cost approximately HK$5.3 per m^3 (circa 2003). The additional charges come from the energy requirements and the chemical treatments, though infrastructure and equipment costs are not factored in. However, there are negligible plans to develop the technology in Hong Kong in the near future.

An ancillary benefit of closing the more traditional linear system is the reduction of wastewater which is discharged into the oceans, thereby also benefiting coastal waters – a key objective stated in the Chief Executive's 2015 Policy Address. The issue has periodically affected our coastline and disrupted marine species.

However, there are numerous alternative uses if treated properly,[302] without going as far as reclaiming water for potable use – as Singapore has done. In Hong Kong, these include:

- Cleaning roads and vehicles;
- Irrigating parks and sport fields;
- Flushing toilets;
- Firefighting;
- Industrial production; and
- Urban development and landscaping.

Optimally, Hong Kong should move towards a closed loop water management system and potentially explore increasing the quality of such water, making it suitable for a wider range of uses.

Rainwater Harvesting

Rainwater is a near-inexhaustible, if seasonal resource that should be harvested and utilised

In 2014, researchers at CityU investigated the use of rainwater for specific, localised activities.[303] Theoretically, were Hong Kong able to harvest all its rainfall, it could be capable of satisfying local demand.[304] However, local topography and extensive urbanisation have rendered such a strategy impracticable.

A collaborative investigation between the DSD and Black & Veatch researchers investigated the feasibility of harvesting stormwater, such as that captured and stored at the Happy Valley Recreation Ground.[305] The 'Happy Valley Underground Stormwater Storage Scheme' (HVUSSS) has a capacity of 60,000 m^3 – equivalent to 24 Olympic swimming pools. It has significantly reduced the flood risk in low-lying parts of the district, yet the waters are underutilised.

The quality of storm- and rainwater is a focal concern. CityU researchers conceded that, while ground-level runoff would be greater in volume than rooftop collection, it would need to be filtered before use, having been exposed to contamination from roads, pavements, etc.[306] Notwithstanding such contamination, Hong Kong's rainwater was found to comply with the WSD's stipulated parameters for the freshwater to be used in its 'Fresh Water Cooling Tower' (FWCT) scheme (Box 15)[307].

Desalination

The proposed desalination plant is expensive to build, maintain and operate, such that other options could be equally, if not more, beneficial

Desalination has been most persistently championed by the government despite the ongoing concerns of LegCo members[308,309,310] and its considerable expense[311,312,313]. The decision to implement this technology defies evidence that other options could be equally, if not more, beneficial to the water security of Hong Kong and the broader region (see Section 5).

The Singaporean government has been pioneering in its development of two seawater desalination plants, SingSpring and the Tuaspring, which satisfy 25% of the nation's freshwater demand.[314] The city-state expects demand to double by 2060 and is planning to construct more plants in order to maintain its rate of 25%. Singapore's absolute commitment to advancing desalination to become a core source for its water, in combination with its numerous alternate and matured taps (i.e. reclamation), contrasts heavily with Hong Kong.

Whilst it would certainly provide a buffer in the event of a shortfall in the regional supply, it remains questionable how beneficial the 5% cushion would be in the event of a drought[315,316].

Further, processing is energy intensive[317] and thus contributes to greenhouse gas emissions. Considering that part of the rationale for adopting alternative strategies is due to water stress[318] exacerbated by climate change[319], a strategy that contributes excess emissions seems counter-productive.

With a host of alternative, more sustainable options (i.e. reducing leakage on private property) available now, the rationale behind the resolute pursuit of desalination at this time remains unclear. Economically, it does appear likely that desalination will be competitive relatively soon[320]; however, the present schedule for construction (barring expensive delays) may leave the facility idle for an extended period (i.e. while the Dongjiang supply is ensured). As long as the Dongjiang supply is guaranteed, the facility is unlikely to operate at an optimal capacity. If the Dongjiang were unable to supply Hong Kong, ten additional and comparable desalination plants operating continuously would be required to satisfy the local demand. Further, there are a number of alternative measures which could be explored and deployed, before desalination.

Expanding/Deepening Existing Reservoirs

Expanding reservoirs and heightening impounding dams are two further strategies that have been explored by the government to address the threat of water scarcity.[321,322,323] The WSD had thought of doing this only for small- and medium-sized reservoirs, which are subject to more frequent overflows from heavy rain than the two larger stores.[324] However, these strategies have long been considered prohibitively expensive, technically challenging, environmentally unfriendly and ultimately "undesirable."[325]

The former Advisory Committee on the Quality of Water Supplies (ACQWS) released a paper in 2002 entitled 'Strategy for Long-term Fresh Water Resource.'[326] In it, the Committee assessed the prices associated with various water sources, conservation and storage strategies. They determined that "Increasing the storage capacities of existing impounding reservoirs is very expensive and does not contribute to the mean local annual yield," and therefore their recommendation was to "not pursue" such a strategy.

The government projected that the cost of freshwater provided from dredging the reservoirs could amount to approximately HK$20 per unit.[327] That is four times the current cost of the local yield and almost double the projected cost of desalinated water, which has been heavily opposed due to expense.

In November 2014, the Under Secretary for Development revealed, "assessments showed that such options were not cost-effective, as the investment and operational cost to further reduce overflow would far exceed the cost of collecting rainwater or even the purchase cost of Dongjiang water."[328]

Whilst presently untenable, dredging the reservoirs could become financially viable in the future as the price for alternative taps increases[329] and freshwater becomes increasingly scarce.

4.4 Effective Demand-Side Management

4.4.1 Improve Water Intelligence, Go Smart Quicker

Smart metering should be deployed rapidly across Hong Kong

In order for the WSD to enhance the efficiency of water usage for domestic and non-domestic uses, as well as improving management and regulation, the department needs to increase its monitoring programme and transparency, and thereby its accountability. It should therefore consider expanding and accelerating its conversion to smart metering under the broader goals of WIN. Until the government has a comprehensive understanding of the entire water system – how the water is used, who and where the biggest consumers are, what the biggest sources of waste are, etc. – it will be near impossible to implement effective strategies to offset or combat them.

The WSD continues to rely on traditional water meters. As a consequence, the department lacks data on daily consumption rates or patterns, hindering its ability to implement effective water planning[330,331].

Smart meters would enable domestic and non-domestic consumers alike to measure and thus potentially reduce consumption. Studies show that using water meters to bill consumers based on their actual consumption can cut water use by 15% or more[332]. It will also aid the WSD in detecting and locating leakages in the inside service[333], which has been an ongoing challenge.

Singapore's PUB has already deployed this approach. Since 2015, all non-domestic consumers using more than 60,000 m^3 of water per year have had to install private smart meters to monitor consumption and submit an annual 'Water Efficiency Management Plan.'[334] Likewise, New York City has required alarms and sub-meters for major water-consuming facilities since 2010.[335]

By converting to such meters, the WSD could then retrain the 155 human meter readers it currently employs to supplement the handful of staff engaged in water-conservation activities, prosecution and other branches of the department.

4.4.2 Improving Transparency and Accountability across the Board

The WSD should encourage accountability, and major water users should release disaggregated water-consumption figures publically

Segmented data on water use by Hong Kong's trade, industry and commercial sectors was not found to be readily available so broad conclusions were necessarily drawn on these sectors. The Hong Kong government should encourage accountability and require its departments, all majority-owned public institutions and major non-listed water users to release their disaggregated water-consumption figures publically. The WSD may consider collating such information to inform a targeted demand-reduction strategy. Otherwise, the sustainability reports of non-listed firms will simply remain token efforts or "greenwashing." Such practices promote a veneer of social and environmental responsibility whilst the company fails to engage in meaningful reforms.

Given the need to conserve water, the companies' ESG reports should also emphasise the importance of data that shows progress over time.

The WSD itself is guilty of opacity, exemplified by its failure to make public the 'Drought Contingency Plan.' Making efforts to increase the departments' transparency on key issues (especially those relevant to public wellbeing) and demonstrating proactivity would improve public confidence.

4.4.3 Improve Public Awareness

The WSD should embark on a more comprehensive public engagement programme that includes education on the responsibilities of consumers and registered users to monitor and maintain the condition of private water infrastructure[336]. This would complement the existing approaches targeting consumer awareness of the need for water conservation and other issues of public concern, such as the quality of its drinking water. The current rhetoric around water issues – referring to it as "precious" – provides no context. The potential threats to supply should be highlighted and government initiatives addressing them should be promoted. Hong Kong could aspire to Singapore's model to effect behavioural change; making conservation an "ingrained habit"[337] and dispel the persistent illusion of plenty.

New strategies need to be developed and adopted for raising awareness about the scarcity of water in Hong Kong

For example, the present emphasis of the government's messaging focuses on the water volumes that are locally available, i.e. how full reservoirs are.[338] This measure promotes a sense of constancy and stability. However, whilst such a metric is comforting, it does not effectively raise awareness or reflect the reality. If the WSD is striving to enhance general awareness and the need to conserve our "precious" water, it might need to consider including measurements that convey the reality. The limitations of the local supply could be emphasised by metrics such as 'number of days to consume,' or other statistics that provide a more personal point of reference.[339]

4.4.4 Set Water Use Targets and Engage the Public

The government could set measurable targets for both domestic and non-domestic users. Notably, the WSD has been criticised by the AC for its failure to set performance targets and indicators to measure the success or efficacy of public campaigns and training sessions.[340] Further, schemes such as the 'Let's Save 10L Water' are too minimalistic in addition to being only voluntary.

In California, cities are trialling personalised schemes whereby consumers work with the water authority to establish household-specific water targets. The utility then provides information on how well the domicile is complying with the target on a monthly basis.[341] Further, certain wasteful practices, such as hosing cars and over-watering lawns, have been banned.[342]

California has succeeded in conserving water by empowering and informing local communities

The WSD has further failed to enforce its conservation strategies.[343] In order to address this, the government should improve its engagement with consumers. California's success in water conservation has largely come from the willing participation of the community, who are well-informed and realise the need to change their behaviour and cooperate with utilities to

reduce their demand. The government may wish to emulate this approach, expanding outreach programmes and inviting the public to dialogue with the WSD on water issues.

Under the Hong Kong Green Building Council's (HKGBC) 'Building Environmental Assessment Method,' (BEAM) credits are awarded for reaching certain objectives. However, the initiative could be revised to prescribe limits, such as maximum volume of freshwater that can be consumed. In China, eco-industrial parks are required to use detailed measurements, set ambitious targets and meet them in order to maintain their accreditation as such.[344]

Furthermore, the government could provide subsidies to join schemes such as WWF's Low-carbon Office Operation Programme (LOOP)[345] (which also includes water), in return for a commitment to cut down water use and report on relevant parameters.

Notably, there is precedent for implementing government-wide environmentally-targeted policies as the ENB issued targets to reduce total electricity consumption throughout government buildings by 5-10% between 2009/10 and 2013/14[346]. However, as yet "there is no government-wide saving target for water consumption," according to the Housing Authority.[347] In light of the administration's positive language, this omission is disappointing.

Nevertheless, various departments have independently sought to reduce water consumption by setting their own targets, which indicates willingness. For instance, between 2015/16 and 2016/17 the Housing Authority established, and is enforcing, its own water conservation target to reduce demand by 2%[348], which is encouraging, if perhaps insufficient.

Regardless of the approach adopted, the WSD should consider abiding by similar target setting and monitoring mechanisms that the Hong Kong government has already committed to under the 2015 Paris Agreement. The Administration has affirmed its commitment to transparently report on and ratchet up an ambitious carbon emissions reduction programme every five years, through which it plans to reduce local emissions 60-65% by 2030 (compared to a 2005 baseline)[349]. A similar approach on water security might be beneficial.

4.4.5 Promote and Incentivise Water Conservation

Contingent on tariff reform (see Section 4.5), a household-level market for water-use trading could be considered. The WSD could 'buy' credits from homes that use below a targeted allocation for water consumption in a year — e.g. by giving them a rebate the following year.

By contrast, Hong Kong offers low-consuming domestic households discounts on their electricity charges. In addition, the two Hong Kong electric utilities have concessionary tariff schemes for poor consumers, so similar concessionary tariffs under a revamped water-pricing regime should be straightforward.[350]

Incentives, rebates, loans or subsidies for water-conserving toilets and low-flow showerheads and taps could help reduce domestic consumption

As in California, the WSD may consider providing incentives, rebates, loans or subsidies for water-conserving toilets and low-flow showerheads and taps[351]. Such targeted subsidies would be especially impactful across Hong Kong's public-rental housing. However, despite pledging to save water, not all participants in schemes like the 'Let's Save 10L Water' project have installed their devices due to restrictions in their buildings[352], the added cost of installation, the lack of incentives and because water use is inexpensive. This may also be an issue with targeting. Lower income families, for instance, who are already accustomed to monitoring and managing their consumption out of necessity (striving to minimise expenses), may not be the consumers that need their behaviour changed.

Accordingly, campaigns should engage households consuming higher volumes of freshwater, such as low to medium density private housing and village houses, and not those in public and government housing estates, which consume less[353].

4.4.6 Along with Other PRD Cities, Explore Water Use Rights

Guangdong is one of the seven provinces in China piloting water-use rights trading schemes[354] and has officially started its 3-year pilot period. According to the provincial 13th Five-Year Plan on Water Resources,[355] the Dongjiang River basin will be the first pilot region for water rights trading.

Schemes, such as water rights trading, could improve the efficiency of water allocation in the Dongjiang catchment and reduce waste

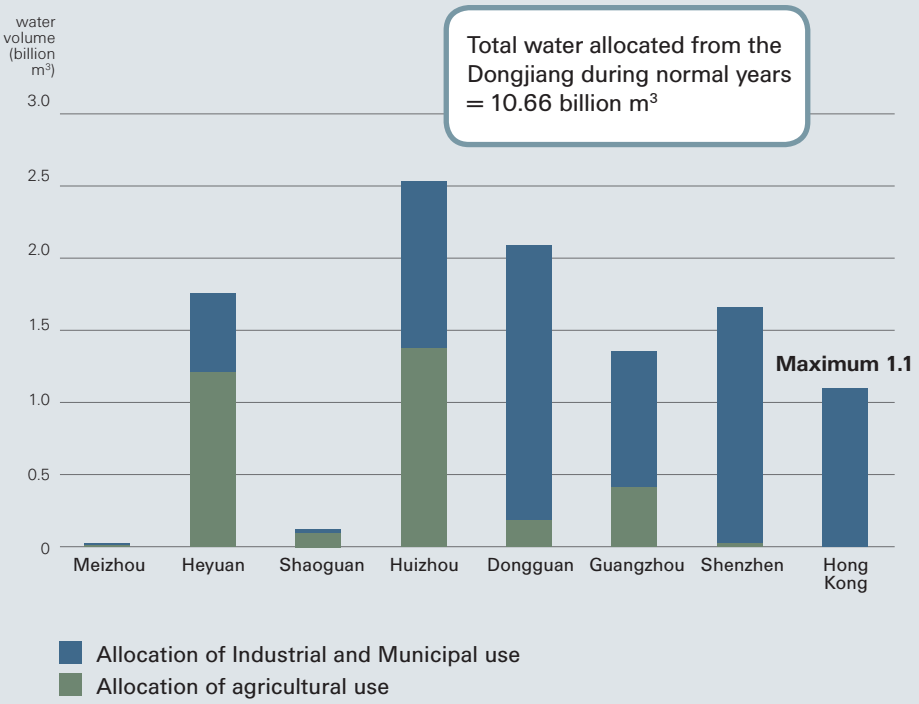
One of the bases for such trading in the Dongjiang River Basin would be the "Dongjiang River Water Resources Allocation Plan"[356] approved by Guangdong's provincial government back in 2008. The plan details the amount of water resources allocated to each city along the river, considering agricultural use and industrial and municipal use. The allocation also differentiates between normal years (Chart 14) and years with severe drought. Since 2008, city governments have also set further targets ranging from district to township level (in the case of Dongguan and Zhongshan).

On the Guangdong side, setting detailed water allocation quotas is in line with the national policies on the 'Most Stringent Water Resources Management'[357] or the so-called "Three Red Lines". The Chinese government has set a total water use cap at national and provincial level for 2015, 2020 and 2030. The water use cap and quota allocation provide the basis for water rights trading between cities.

CHART 14

WATER ALLOCATION OF THE DONGJIANG RAW WATER IN NORMAL YEARS

Source: ADMCF, based on data from Guangdong People's Government, 2008



Hong Kong should do its utmost to promote regional harmony through seeking opportunities to address water conservation

For the next five years, Hong Kong should do its utmost to promote regional harmony through seeking opportunities to address water conservation. It should explore strengthening collaboration with PRD authorities, including the potential for water rights trading, to be piloted along the Dongjiang as a mechanism for harmonising water use with our neighbours.

In other areas, such as connecting stock exchanges[358], combating climate change[359] and promoting cleaner production[360], Hong Kong has already explored close collaboration with its counterparts across the border. The same could potentially be done for its water supply.

Moreover, Hong Kong could also explore the option of water rights trading among different users within the city by learning from other cities with schemes such as Guangzhou, which is establishing such a trading system[361].

4.5 Long-Awaited Tariff Reform

Hong Kong undoubtedly needs tariff review and reform given both the lack of success in achieving its policy objectives and the stagnation of water pricing over two decades, despite the increasing value of the resource.

Tariffs for water need to be reviewed and reformed strategically, so that the poorest members of society are not negatively impacted

While the WSD may be able to resolve its annually recurring billion-dollar deficit through incentive-stimulated innovation, it ultimately requires a stable financial base to initiate such a strategy and this will be assisted by tariff reform.

Moreover, failure to raise tariffs disincentivises the WSD to promote water conservation, as its revenues are at least partially dependent on income from tariff charges.

The question of how to reform the tariff system must be informed by clear and realistic policy objectives that consider the complexities of local price elasticity. With approximately 14% of Hong Kong residents living below the poverty line[362], it is imperative that access to clean water is not compromised. Nevertheless, there is certainly scope for those that earn more to pay more, without disadvantaging those on lower incomes[363]. Options could include:

- **Discontinuing the free allocation** for all but the financially disadvantaged. Or, alternatively discontinuing the allocation universally while ensuring that the CSSA water/sewage allowance or other schemes subsidise those in need appropriately. Ultimately, the objective is for a mechanism whereby those who can afford to pay, do not benefit from free water.

  Free allotments of water are rare for developed economies. Hong Kong's neighbours, Macao Water[364], the Shenzhen Water Group[365] and the Guangzhou Water Affairs Bureau[366] offer subsidies (or similar) to poor households, rather than universal free allotments on initial water tranches.

- **Continuing with the universal free allocation and raising water charges for consumption of the second tier (above 12 m^3 at least to HK$6.45 per m^3).** This minimal increase could add a maximum of 0.01% to household's monthly expenses for those not using more than the allotted volumes for the first and second tiers (who represent the majority of consumers).

Notably, Macao Water has also raised prices gradually as needed, without complaints from the public, including a 3% price rise in 2014.[367] Singapore has mandated water conservation since 1991, deploying a tax set at 30% of the tariff for all units of water consumed by non-domestic consumers and the first 40 m^3 consumed by domestic consumers in each month.[368] A higher rate (45%) is charged to domestic consumers using in excess of 40 m^3. In combination with mandating and promoting more efficient appliances, as well as increasing public awareness, the city reduced daily per capita consumption from 165 litres in 2003 to 150 litres by 2014. Further, the water tariff in Singapore recovers "full production and supply costs."

However, for any reform, it is paramount that, where relevant, such approaches are accompanied by campaigns to advise low-income households on how to apply for rebates/allowances. Tariff reform is not a 'silver bullet' and must be a part of an holistic strategy.

5 BALANCING OPTIONS AT A GLANCE

For Hong Kong to ensure a water secure future, it must implement water management strategies in harmony with the PRD. Naturally, the optimal strategy must balance and ultimately prioritise alternatives based on cost, environmental impact, feasibility, volume of water saved or produced, as well as public concerns.

In the following section, various scenarios are reviewed and compared:-

i) The present state of affairs;
ii) Strategies advanced by the government under its TWM Strategy;
iii) An alternative approach that optimises and expands on the proposals posited in ii); and
iv) A comparison of the savings that might be achieved by 2030, depending on the strategies adopted.

5.1 Current State of Affairs: Non-Revenue Water (NRW)

This report has highlighted the persistent issue of significant water loss (non-revenue water) from the supply network. Approximately one-third of water supplied remains unaccounted for as a result of illegal withdrawals, meter inaccuracy and leakage.

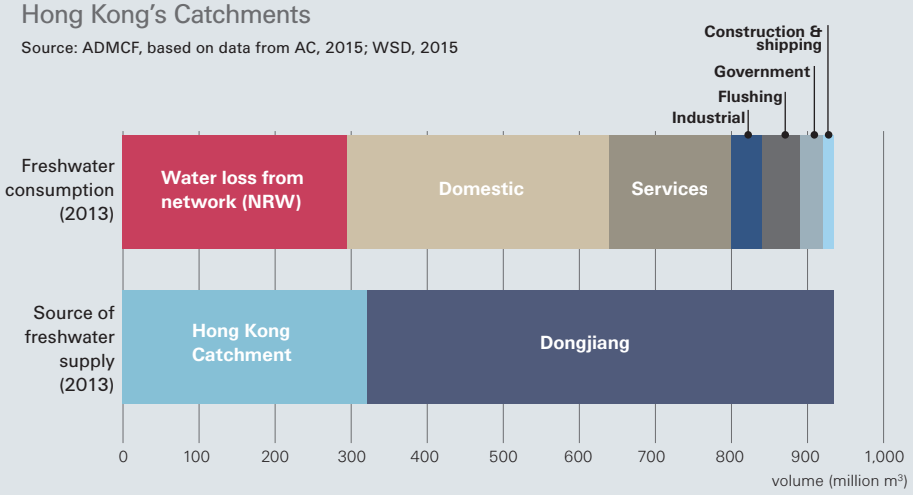
The volume of NRW frequently exceeds the average volume of freshwater provided by Hong Kong's own catchments. As illustrated below (Chart 15), in 2013 (the last year for which sector data is publically available), NRW was equivalent to 92% of Hong Kong sourced freshwater, or 48% of the water supplied by the Dongjiang. By sector, NRW equated to

CHART 15

FRESHWATER CONSUMPTION BY SECTOR: STATUS QUO

Highlighting NRW, Compared to Supply from Dongjiang and Hong Kong's Catchments

Source: ADMCF, based on data from AC, 2015; WSD, 2015



Note: In 2013, local rainfall was high, with the supply from local catchment 36% higher than average over the period 2004-2013.

86% of domestic freshwater consumption and exceeded all remaining sectors combined. Measures to address NRW should therefore be a key component of any future strategy as this will make significant contributions to reducing water supplied.

5.2 The Government's Proposed Water Savings under the 2008 Total Water Management Strategy

Under its TWM Strategy, the WSD has pledged to expand and diversify local taps. The combination of approaches identified in the TWM Strategy (Chart 16) aims to:

i) Save 236 million m^3 of water annually by 2030[369] via a combination of conservation, reclamation, leakage control and increasing seawater for flushing; and

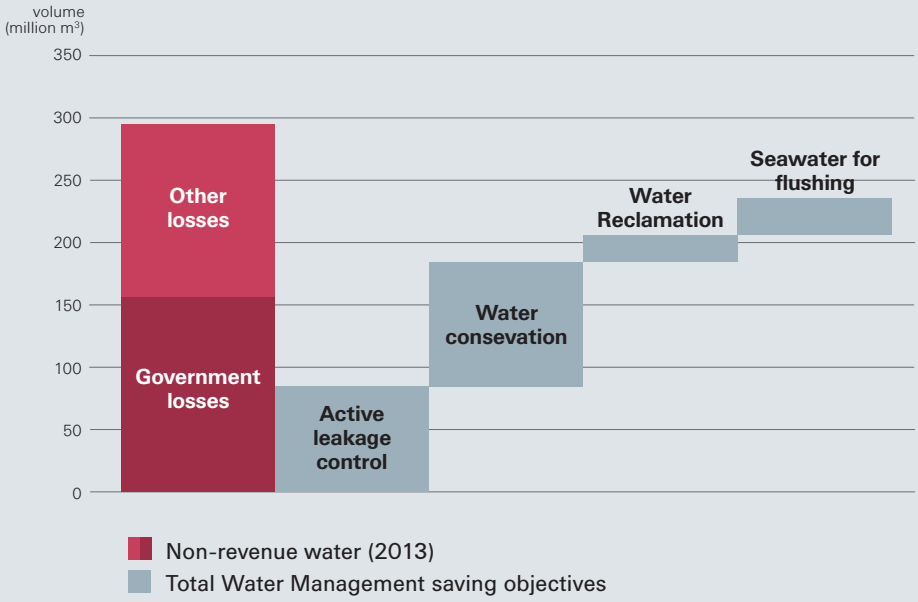
ii) Offset water shortages via a new desalination plant, initially with a capacity to produce up to 5% of current daily demand and a future capacity of 10%.[370] If the TKO Plant were to operate 365 days a year, it could be capable of producing 99 million m^3 of water equivalent to 33% of NRW or 9% of projected demand in 2030[371,372].

The strategy of progressively addressing NRW through 'Active Leakage Control' could amount to a saving of 85 million m^3 per year by 2030. This equates to just 29% of the NRW as it stood in 2013, indicating the clear need to ramp up NRW reduction into the future[373].

CHART 16

ANNUAL WATER SAVINGS UNDER THE TWM STRATEGY, HIGHLIGHTING NRW LOSSES

Sources: ADMCF, based on data from Wong & WSD, 2015; AC, 2015; DevB, 2008



5.3 An Alternative Strategy: Optimising Water Supply

Informed by the findings of this report, an alternate approach is proposed that illustrates the inadequacy of the TWM Strategy. The focus has been on addressing areas where government performance has been lacklustre and where renewed action could result in significant water savings. In line with the Strategy, the proposed measures would ideally be fully realised by 2030. These comprise:

Reclaiming 15% of Wastewater

Under this scenario, reclaiming just 15% of Hong Kong's wastewater could provide approximately 165 million m^3 of freshwater that could be repurposed for non-potable tasks. This is eight times the volume originally proposed by the WSD. Reclaimed water could be further deployed as an alternative to converting the remainder of the flushing network from freshwater to seawater. On the grounds of increased expense, infrastructure strain and reduced benefit with the arrival of low volume flushing, it is speculated that conversion of the remaining freshwater flushing infrastructure could be abandoned in favour of reclaimed water. A portion of reclaimed water from the proposed 15% could be a suitable and comparatively inexpensive solution to reduce reliance on freshwater for flushing. This view is in line with recommendations made by the WSD in 2016[374].

Addressing Non-Revenue Water

- Reducing leakage rate from government mains by 10% (from 15% to 5%)
- Reducing leakage rate from private property by 4% to approximately 7%
- Reducing unauthorised withdrawals by 50% (assuming such losses are currently 2% of water supplied)
- Reducing inaccurate metering by 50% (assuming such losses are currently 2% of water supplied)

It is clear that losses from the network not only represent a significant challenge, but also the greatest opportunity to reduce Hong Kong's consumption in the near term. Under this scenario, by directly tackling the four core elements of NRW (government mains leakage, leakage on private property, illegal connections and inaccurate metering), 176 million m^3 of freshwater could be saved annually by 2030, more than doubling the expected savings of the TWM Strategy's 'Active Leakage Control'.

Addressing Demand-Side Management

- Expand the 'Let's Save 10L Water' campaign to a 'Let's Save 20L Water' campaign (assuming 100% engagement of a population of 8 million by 2030)

Savings under the current 10L campaign represent less than 10% of domestic users' daily demand. Doubling this to 20L would be reasonable and achievable, considering the markedly lower consumption rates observed in other similarly developed cities. Whilst the cumulative benefit would be a comparatively small fraction of overall savings, the increased volume to be pledged could raise awareness of the need to conserve.

In combination with the planned strategies under the TWM Strategy, which are largely centred on enhancing public education and the 'Water Efficiency Labelling Scheme', up to 129 million m^3 might be saved, a 23% increase from the original plans for demand-side management.

Combined Benefits

Overall, the combined benefits of this alternative strategy could secure a volume equivalent to 24% of Hong Kong's annual freshwater demand projected by 2030, adding to the approximately 20% of savings achieved through the 2008 TWM Strategy, as it stands (Chart 17).

Complementing the rainwater provided from Hong Kong's catchments, this water would allow the WSD to reduce the volume required from the Dongjiang. It should be noted that the supply from the Dongjiang would remain a critical source, continuing to provide more than half of the supply

by 2030 (Chart 18). However, reducing Hong Kong's water consumption and losses by between 30-40% would be a major step toward enhancing Hong Kong's resilience and contributing to water security within the PRD.

Assuming Hong Kong's water supply remains comparable with present levels (1995-2015), the reliance on Dongjiang water could potentially decrease from its current 60-80% today to 40-60% by 2030.

CHART 17

AN ALTERNATIVE STRATEGY – POTENTIAL ANNUAL WATER SAVINGS BY 2030

Source: ADMCF, based on data from WSD, 2015; DevB, 2008

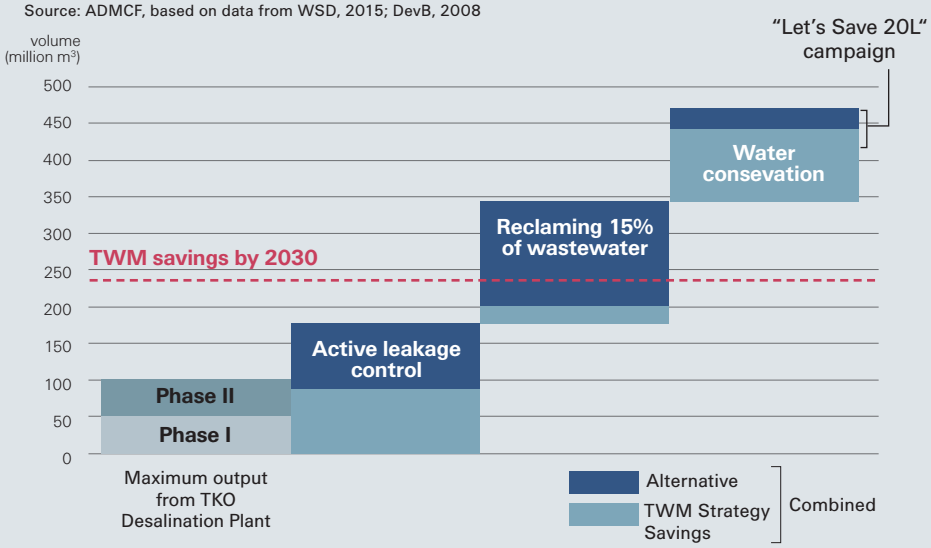
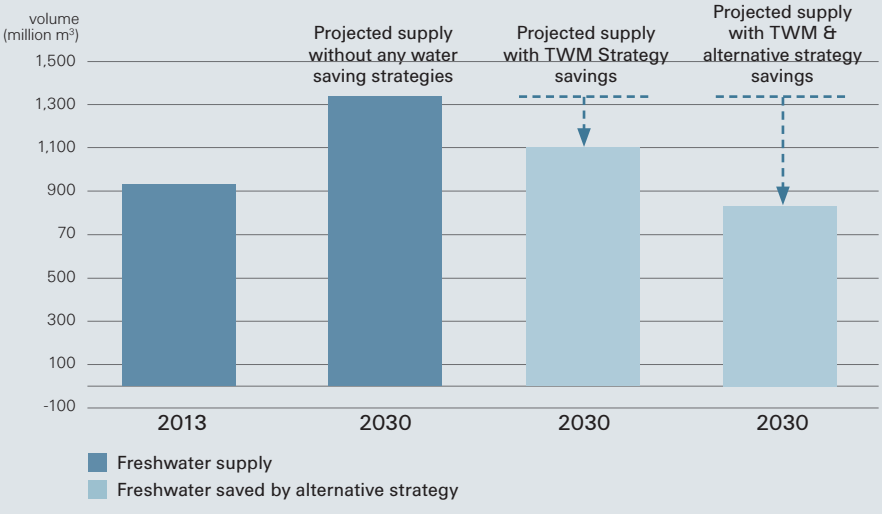


CHART 18

POTENTIAL SAVINGS ACHIEVED THROUGH ALTERNATIVE 2030 STRATEGY

Source: ADMCF, based on data from WSD, 2015



5.4 Other Issues To Consider

Costs

The government's insistence on developing desalination raises the question of cost-effectiveness. As highlighted, there are a variety of alternative taps and conservation measures available, suitable for development and deployment. Due to multiple variables in implementing scenarios, it is not possible with current available data to apply a specific cost to the scenarios. However, some insight can be gained by comparing the production cost of water:

According to the government:

- Raw water from the Dongjiang (including processing and distribution) costs HK$9.1 per m^3.[375]
- Local waters, captured within Hong Kong's catchments and stored within the Hong Kong's 17 reservoirs, cost just HK$4.2.[376]
- Reclaimed water could cost as little as HK$3.8.[377]
- Desalination, by contrast, is expected to cost HK$12.6 per unit[378] – three times the cost of other locally-sourced freshwater and 38% higher than processed Dongjiang water. The disparity increases when the cost of saving water is considered.

Since the R&R programme began, the per unit value of water saved was approximately HK$0.96-1.44.

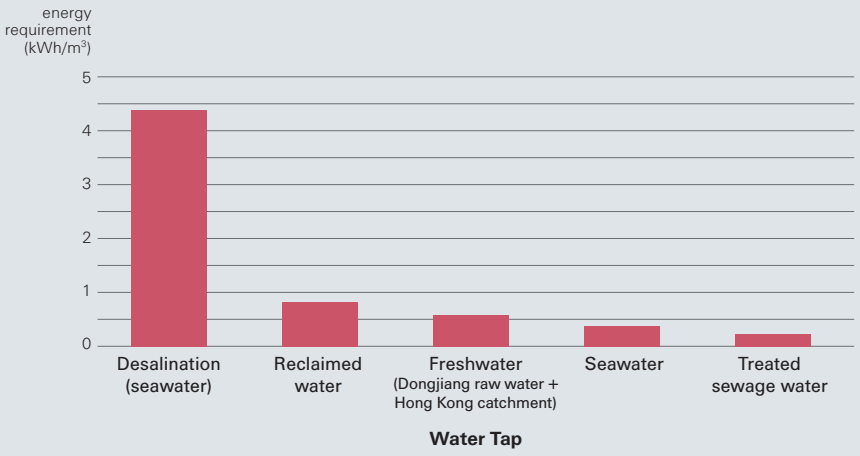
Energy Requirements of the Varied Taps

There are also considerable disparities among the energy requirements of each of the taps under consideration or that are currently deployed (Chart 19).

CHART 19

ENERGY REQUIREMENTS FOR VARIOUS METHODS OF WATER PRODUCTION IN HONG KONG

Source: Water Supplies Department, 2015, 2016; WRI, 2014



Seawater for flushing remains the least energy-intensive option[379], a benefit of being a coastal city. Treated freshwater, sourced from both the Dongjiang and Hong Kong catchments, has a combined intensity of 0.58 kWh per m^3 of water produced.

Desalination at the TKO facility is expected to require 4.4 kWh per m^3 of water produced. Considering just the energy demands of production, desalination is 7.5 times more energy-intensive than conveying freshwater.

Furthermore, once distribution is considered, it is likely that desalination would consume a further 0.38-0.58 kWh per unit, consistent with transfers of fresh and seawater, bringing total demand to between 4.79 and 4.98 kWh per unit. The energy intensity of desalination should not be overlooked given climate change has been exacerbated by GHGs[380], especially since the WSD already accounted for 53.8% of governmental energy consumption in 2014-15[381].

6 CONCLUSION – DISPELLING THE ILLUSION OF PLENTY

Worldwide, the availability of freshwater is decreasing in response to rising population levels, urbanisation and increasing demand, with the impact of all being exacerbated by climate change.

With limited water resources of its own and an equally limited capacity to store rainwater, Hong Kong relies on the PRD catchment for the majority of the water it consumes. Climate change and uncertainties concerning competing demands and supply within the PRD itself have increasingly raised questions as to Hong Kong's vulnerability to water shortages and demonstrated the need for Hong Kong to better manage its own resources.

Such concerns have largely grown out of the Hong Kong government's lacklustre performance in developing a visionary and vigorous water management strategy that would ensure Hong Kong's water security for the future. It has failed to manage its water supplies judiciously, instead taking more water from China than should otherwise be necessary. Perversely, the lack of innovation and aspiration in supply-side management has been nurtured by the steady supply of water from China and a water agreement that does little to encourage conservation.

Hong Kong faces numerous challenges. Policy gaps exist that are, to some extent, the consequence of a complicated governance structure and multiple layers of authority. Underperformance in multiple areas has been persistently highlighted by the government's own AC.

The government's determination to develop desalination, despite opposition from LegCo Members, expense, energy use and little proof of benefit, has taken considerable focus, time and money. The sporadic nature of its operation, i.e. during periods of drought, also means that the plant will be a last resort, only periodically offsetting a small portion of overall demand.

Attempts at demand-side management have further had little effect on the high volumes of water consumed across the city. Meanwhile, the tariff system has remained unchanged for two decades and does little to recover the costs of supply, nor does it place adequate value on a precious resource. Ultimately, the government needs to take significant action to raise awareness and dispel Hong Kong's illusion of plenty.

Perhaps most startling is the lack of attention the government's TWM Strategy pays to what appears to be an increasing trend of water losses from its system. Whilst the TWM Strategy includes the R&R programme, it fails to account for losses from the inside service. Developing a more comprehensive and robust strategy could potentially save considerable volumes of water, equivalent to about one quarter of the volume projected to be supplied to Hong Kong's consumers in 2030.

Steering towards a circular water system by focusing on reclaiming water and increasing rainwater harvesting, combined with loss reduction may reduce the quantity taken from the Dongjiang and move Hong Kong towards a more water secure future.

In reviewing its TWM Strategy, it is hoped the government will consider such approaches ahead of desalination and in doing so, demonstrate its commitment towards sustainable development in harmony with the PRD.

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95. Legislative Council (2014) *Panel on Development: Supply of Dongjiang Water* (Ref: CB(1)89/14-15(07)), p. 3.
96. Lee, F. (2016) *Personal Communication*, 16 November.
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98. Legislative Council (2014) *Panel on Development: Supply of Dongjiang Water* (Ref: CB(1)89/14-15(07)), p. 1.
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100. Global Water Partnership (2015) *China's water resources management challenge: The 'three red lines'*. Available at: http://www.gwp.org/Global/ToolBox/Publications/Technical%20Focus%20Papers/TFPChina_2015.pdf (Accessed: 5 November 2016), p. 7.
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109. Flow controllers are devices which regulate the flow of water, with the intention of reducing flow rates, and thereby water consumption. Hong Kong's voluntary 'Water Efficiency Labelling Scheme' (WELS) on Flow Controllers has been in effect since August 2014. (Source: Water Supplies Department (2014) *The Voluntary Water Efficiency Labelling Scheme on Flow Controllers*. Available at: http://www.wsd.gov.hk/filemanager/en/content_967/scheme_document_flow_controllers.pdf (Accessed: 9 January 2017).)
110. Water Supplies Department (2015) *Annual Report 2014/15 - Combat Against Climate Change: Exploit new water resources and foster water conservation culture*. Available at: http://www.wsd.gov.hk/filemanager/common/annual_report/2014_15/pdf/wsd_annual_report2014-2015.pdf (Accessed: 7 September 2016), p. 40.
111. Lee, F. (2017) *Personal Communication*, 7 March.
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113. Water Supplies Department (2015) *Annual Report 2014/15 - Combat Against Climate Change: Exploit new water resources and foster water conservation culture*. Available at: http://www.wsd.gov.hk/filemanager/common/annual_report/2014_15/pdf/wsd_annual_report2014-2015.pdf (Accessed: 7 September 2016), p. 37.
114. Ibid., p. 28.
115. Development Bureau (2016) '*My Blog: Review of Total Water Management Strategy*', 25 April. Available at: https://www.devb.gov.hk/en/home/my_blog/index_id_174.html (Accessed: 19 January 2017).
116. Ministry of Environmental Protection of the People's Republic of China (2002) 地表水环境质量标准 (GB 3838-2002) [in Chinese]. Available at: http://kjs.mep.gov.cn/hjbhbz/bzwb/shjbh/shjzlbz/200206/t20020601_66497.htm (Accessed: 7 September 2016).
117. In 2015/16, the WSD collected approximately 173,500 samples from across the entire network (including intakes, impounding reservoirs, water treatment works, service reservoirs, trunk-mains and consumers' taps), of which 98.3% were tested. However relatively few tests in Hong Kong are believed to be conducted on water from private premises. In 2001, the WSD took approximately 25,000 samples from throughout the distribution network, explicitly stating that it was taking "water samples from household water taps for laboratory tests," however, no further data has been provided.

118. Water Supplies Department (2016) *Water Quality Monitoring Data*. Available at: http://www.wsd.gov.hk/en/water_resources/water_quality/water_quality_monitoring_data/index.html (Accessed: 23 September 2016).

119. World Health Organization (2011) *Guidelines for Drinking-water Quality*. Available at: http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf (Accessed: 19 September 2016).

120. Water Supplies Department (2016) *Examination of Estimates of Expenditure 2016-17 - Controlling Officer's reply (Question Serial No. 3879)*, pp. 600-601.

121. Food and Environmental Hygiene Department and Buildings Department (2005) *ACFEH Paper 59 - Joint Office on Water Seepage*. Available at: http://www.fhb.gov.hk/en/committees/board/2006/paper20050323_59.html (Accessed: 30 September 2016).

122. Office of The Ombudsman (2008) *Direct Investigation Handling of Water Seepage Complaints*. Available at: http://www.ombudsman.hk/direct_investigation2.html (Accessed: 30 September 2016).

123. Ibid., p. 12.

124. Audit Commission (2016) 'Chapter 9: Joint-office operation on water seepage in buildings', in *Director of Audit's Report No. 67*. Hong Kong SAR: Government of the Hong Kong SAR, p. iv-ix.

125. *Chapter 102 - Waterworks Ordinance1997*a, c. Available at: http://www.legislation.gov.hk/blis_pdf.nsf/CurEngOrd/8D9A4D0194F0DD92482575EE0039A138/$FILE/CAP_102_e_b5.pdf (Accessed: 20 September 2016).

126. Water Supplies Department (2016) Water Quality: My Drinking Water Quality. Available at: http://www.wsd.gov.hk/en/water_resources/water_quality/my_drinking_water_quality/index.html (Accessed: 14 January 2017).

127. The WSD appears to have been subject to more investigations by AC and The Ombudsman than any other government department during the past decade, and has been brought before LegCo several times, in successive years, on the AC's recommendation. This only occurs when a department fails to adequately act upon the AC's findings, and is rare.

128. Audit Commission (2004) 'Chapter 5: Mainlaying works', in Report No. 42 of *the Director of Audit. Hong Kong SAR: Government of the Hong Kong SAR*, p. 11.

129. Water Supplies Department (2016) *Staging of the works*. Available at: http://www.wsd.gov.hk/en/replacement_and_rehabilitation_programme_of_water/staging_of_the_works/index.html (Accessed: 12 January 2017).

130. Undoubtedly, leakage on private property is challenging to address, yet, as concluded by the Office of The Ombudsman "it is an important work target of the department responsible for water supply…to ensure that there is no leakage in all water supply facilities (public water supply facilities and private water pipes inclusive),and that proper repair works are carried out as soon as there is a leak." (Source: The Office of The Ombudsman (2015) Direct Investigation into Water Supplies Department's Mechanism for Handling Leaks of Private Water Pipes - Annex I. Available at: http://ofomb.ombudsman.hk/abc/files/Annex_1_E_0.pdf (Accessed: 13 February 2017), p. 1.)

131. Audit Commission (2011) 'Chapter 12: Water losses from unauthorised consumption and inaccurate metering', in *Director of Audit's Report No. 57*. Hong Kong SAR: Government of the Hong Kong SAR, pp. 26,31.

132. Audit Commission (2008) 'Chapter 3: Customer Care and Billing System of the Water Supplies Department', in *Director of Audit's Report No. 50*. Hong Kong SAR: Government of the Hong Kong SAR, p. 32.

133. Audit Commission (1999) 'Chapter 12: Water purchased from Guangdong Province', in *Director of Audit's Report No. 33*. Hong Kong SAR: Government of the Hong Kong SAR, pp. 30-31.

134. Audit Commission (2010) 'Chapter 8: Water supplies department managing and reducing water main bursts and leaks', in *Director of Audit's Report No. 55*. Hong Kong SAR: Government of the Hong Kong SAR, p. 18.

135. Chan, A.H.W. and Lai, A.N. (2016) *Report of the Commission of Inquiry into Excess Lead Found in Drinking Water (Redacted Version)*. Available at: http://www.coi-drinking-water.gov.hk/eng/pdf/COI%20Drinking%20Water_Report.pdf (Accessed: 24 September 2016), p. 125.

136. In the most recent fiscal year, the WSD devoted only 16 of its 4,400 staff and HK$15 million (less than 0.2% of its budget) to water-conservation measures. (Source: Water Supplies Department (2015) *Examination of Estimates of Expenditure 2015-16 - Controlling Officer's reply (Question Serial No. 3097)*, p. 265.)

137. The AC's repeated investigations revealed shortcomings within the department which could have been addressed at any point, such as improving oversight of contractors, public relations, and staff training.

138. Chan, A.H.W. and Lai, A.N. (2016) *Report of the Commission of Inquiry into Excess Lead Found in Drinking Water (Redacted Version)*. Available at: http://www.coi-drinking-water.gov.hk/eng/pdf/COI%20Drinking%20Water_Report.pdf (Accessed: 24 September 2016), pp. 158-165.

139. The Office of The Ombudsman (2015) *Direct Investigation into Water Supplies Department's Mechanism for Handling Leaks of Private Water Pipes - Annex I*. Available at: http://ofomb.ombudsman.hk/abc/files/Annex_1_E_0.pdf (Accessed: 13 February 2017), pp. 1-8.

140. Water Supplies Department (2017) *Annual Report 2015/16 – Water security and climate resilient development*. Available at: http://www.wsd.gov.hk/filemanager/common/annual_report/2015_16/common/pdf/wsd_annual_report2015-2016.pdf (Accessed: 5 April 2017), p. 31.

141. Dr Ji Chen of HKU drafted 'A Preliminary Drought Mitigation Plan for Hong Kong' in 2007, and is an expert on water resources in the PRD and the Dongjiang specifically. Despite his expertise, he had no awareness of the DCP when interviewed in January 2017, notwithstanding his regular correspondence and collaboration with the WSD.

142. Chen, J. and Chan, F.P. (2007) 'A preliminary drought mitigation plan for Hong Kong', *MODSIM07 - Land, Water and Environmental Management: Integrated Systems for Sustainability, Proceedings*, p. 1494.

143. Water Supplies Department (2016) *Personal Communication*, 16 February.

144. Research Office (2015) *Research Brief: Water resources in Hong Kong*. Available at: http://www.legco.gov.hk/research-publications/english/1415rb05-water-resources-in-hong-kong-20150611-e.pdf (Accessed: 7 September 2016), p. 8.

145. Legislative Council (2014) *Panel on Development: Supply of Dongjiang Water* (Ref: CB(1)89/14-15(07)), p. 3.

146. Water Supplies Department (2017) Personal Communication, 10 April.

147. Water Supplies Department (2017) Personal Communication, 19 April.

148. Shou, S. (2013) 'Science in brief', *Journal of the Hong Kong Institution of Engineering Online*, 15 August. Available at: http://www.hkengineer.org.hk/program/home/articlelist.php?cat=article&volid=171 (Accessed: 15 December 2016).

149. Development Bureau (2015) *My Blog: The Water Intelligent Network. Available* at: https://www.devb.gov.hk/en/home/my_blog/index_id_121.html (Accessed: 14 December 2016).

150. Water Supplies Department (2017) *Annual Report 2015/16 – Water security and climate resilient development*. Available at: http://www.wsd.gov.hk/filemanager/common/annual_report/2015_16/common/pdf/wsd_annual_report2015-2016.pdf (Accessed: 5 April 2017), p. 23.

151. Water Supplies Department (2017) Personal Communication, 22 March.

152. Water Supplies Department (2015) *Annual Report 2014/15 - Combat Against Climate Change: Exploit new water resources and foster water conservation culture*. Available at: http://www.wsd.gov.hk/filemanager/common/annual_report/2014_15/pdf/wsd_annual_report2014-2015.pdf (Accessed: 7 September 2016), pp. 23-24.

153. Planning Department (2007) *Hong Kong 2030: Planning vision and strategy - Final Report*. Available at: http://www.pland.gov.hk/pland_en/p_study/comp_s/hk2030/eng/finalreport/pdf/E_FR.pdf (Accessed: 19 January 2017).

154. Planning Department (2016) *Green and Blue Space Conceptual Framework*. Available at: http://www.hk2030plus.hk/document/Green%20and%20Blue%20Space%20Conceptual%20Framework_Eng.pdf (Accessed: 19 January 2017), p. 39.

155. Planning Department (2016) *Hong Kong 2030+: A Smart, Green and Resilient City Strategy*. Available at: http://www.hk2030plus.hk/document/Hong%20Kong%202030+%20A%20SGR%20City%20Strategy_Eng.pdf (Accessed: 19 January 2017), p. 30.

156. Ibid., p. 44.

157. Ibid., p. 72.

158. Greywater infrastructure is currently under consideration for the Anderson Road Quarry site, intended to treat water for flushing purposes.

159. Development Bureau (2015) *'Smart city initiative in Kowloon East'*, Hong Kong SAR. Available at: https://www.ekeo.gov.hk/filemanager/content/speeches_and_presentations/en/Smart_City_Initiative_in_Kowloon_East_Final_lo.pdf (Accessed: 14 December 2016).

160. Government of the Hong Kong SAR (2016) *The 2016 Policy Address: Innovate for the Economy, Improve Livelihood, Foster Harmony, Share Prosperity*. Available at: http://www.policyaddress.gov.hk/2016/eng/pdf/PA2016.pdf (Accessed: 21 September 2016), pp. 20-25.

161 Government of the Hong Kong SAR (2016) *The 2016 Policy Address: Innovate for the Economy, Improve Livelihood, Foster Harmony, Share Prosperity*. Available at: http://www.policyaddress.gov.hk/2016/eng/pdf/PA2016.pdf (Accessed: 21 September 2016), p. 57.

162. Development Bureau (2012) *Energizing Kowloon East*. Available at: http://www.ekeo.gov.hk/en/home/index.html (Accessed: 25 January 2017).

163. Hong Kong Exchanges Clearing Limited (2010) *Appendix 27 - Environmental, Social and Governance Reporting Guide*. Available at: http://en-rules.hkex.com.hk/en/display/display_main.html?rbid=4476&element_id=3841 (Accessed: 25 January 2017).

164. Swire Pacific Limited (2016) *Annual Report 2015*. Available at: http://www.swirepacific.com/en/ir/reports/ar15.pdf (Accessed: 20 September 2016), p.4.

165. Ocean Park Corporation (2015) *Annual Report 2014-2015*. Available at: http://media.oceanpark.com.hk/files/s3fs-public/ophk_ar14-15.pdf (Accessed: 27 September 2016), p. 22.

166. Such as provided by Vita.

167. Consumer Council (2017) *Online Price Watch: Mineralized water*. Available at: https://www3.consumer.org.hk/pricewatch/supermarket/index.php?view=0&filter1=027&filter2=006&filter3=010 (Accessed: 13 April 2017).

168. Water Supplies Department (2013) *Domestic Water Consumption Survey: Key Survey Findings*. Available at: http://www.wsd.gov.hk/filemanager/en/content_523/factsheet_e.pdf (Accessed: 7 September 2016).

169. The WSD monitored 1,028 households between September 19th and January 15th 2012.

170. Wong, C.L. and Water Supplies Department (2015) 'Appendix 44 - Public accounts committee consideration of Chapter 4 of the management of water supply and demand', in *Director of Audit's Report No. 64*. Hong Kong SAR: Public Accounts Committee, p. 511.

171. Advisory Committee on Water Resources and Quality of Water Supplies (2012) *Minutes of Meeting No. 2 - 16 August 2012*. Available at: http://www.wsd.gov.hk/acqws/filemanager/common/ACRQWS_minutes2.pdf (Accessed: 25 January 2017), p. 4.

172. Audit Commission (2015) 'Chapter 4: Management of water supply and demand', in Sun, D. (ed.) *Director of Audit's Report No. 64*. Hong Kong SAR: Government of the Hong Kong SAR, Appendix C, pp. 57-58.

173. Ibid., p. x.

174. Government of the Hong Kong SAR (2016) *The 2016 Policy Address: Innovate for the Economy, Improve Livelihood, Foster Harmony, Share Prosperity*. Available at: http://www.policyaddress.gov.hk/2016/eng/pdf/PA2016.pdf (Accessed: 21 September 2016), p. 116.

175. Water Supplies Department (2017) Annual Report 2015/16 – Water security and climate resilient development. Available at: http://www.wsd.gov.hk/filemanager/common/annual_report/2015_16/common/pdf/wsd_annual_report2015-2016.pdf (Accessed: 5 April 2017), p. 74.

176. Hong Kong Construction Association (2016) *Personal Communication*, 16 January.

177. Hong Kong's consumption in this sector is not helped by regulation that, while undoubtedly exemplary from a health and safety perspective, results in the use of highly treated freshwater for menial tasks. Stringent regulation on the use of reclaimed water has stipulated that unless there is zero percent e-coli bacteria (the standard maintained for drinking water), such water cannot be deployed at construction sites for controlling dust, unless workers wear costly and cumbersome hazmat suits. As a result, Hong Kong's many construction sites use potable, rather than more appropriate and sustainable recycled or reclaimed water for cleaning activities, dust control, and so on.

178 Lo, J.Y., Chan, W.W. and Wong, K. (2011) 'A comparison of cold-water thawing options in Chinese restaurants', *Cornell Hospitality Quarterly*, 52(1), doi: 10.1177/1938965510389427, pp. 64–72

179. The EPD still has a webpage, available via: http://www.epd.gov.hk/epd/misc/ehk99/home/english/ch8/p208frm.htm.

180. Government of the Hong Kong SAR (2016) *The 2016 Policy Address: Innovate for the Economy, Improve Livelihood, Foster Harmony, Share Prosperity*. Available at: http://www.policyaddress.gov.hk/2016/eng/pdf/PA2016.pdf (Accessed: 21 September 2016), p. 116.

181. It remains unclear how much water is lost from the network during the WSD's rigorous process of treatment.

182. Ma, L.T. (2012) *The Director of Audit's Report on the results of value for money audits (Report No. 57)*; Water losses from unauthorised consumption and inaccurate metering (Chapter 12). Available at: http://www.legco.gov.hk/yr11-12/english/pac/reports/57/app_17.pdf (Accessed: 30 September 2016), p. 207.

183. Audit Commission (2015) 'Chapter 4: Management of water supply and demand', in Sun, D. (ed.) *Director of Audit's Report No. 64*. Hong Kong SAR: Government of the Hong Kong SAR, p. 23.

184. Water Supplies Department (2016) *Examination of Estimates of Expenditure 2016-17 - Controlling Officer's reply* (Question Serial No. 0409), p. 232.

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