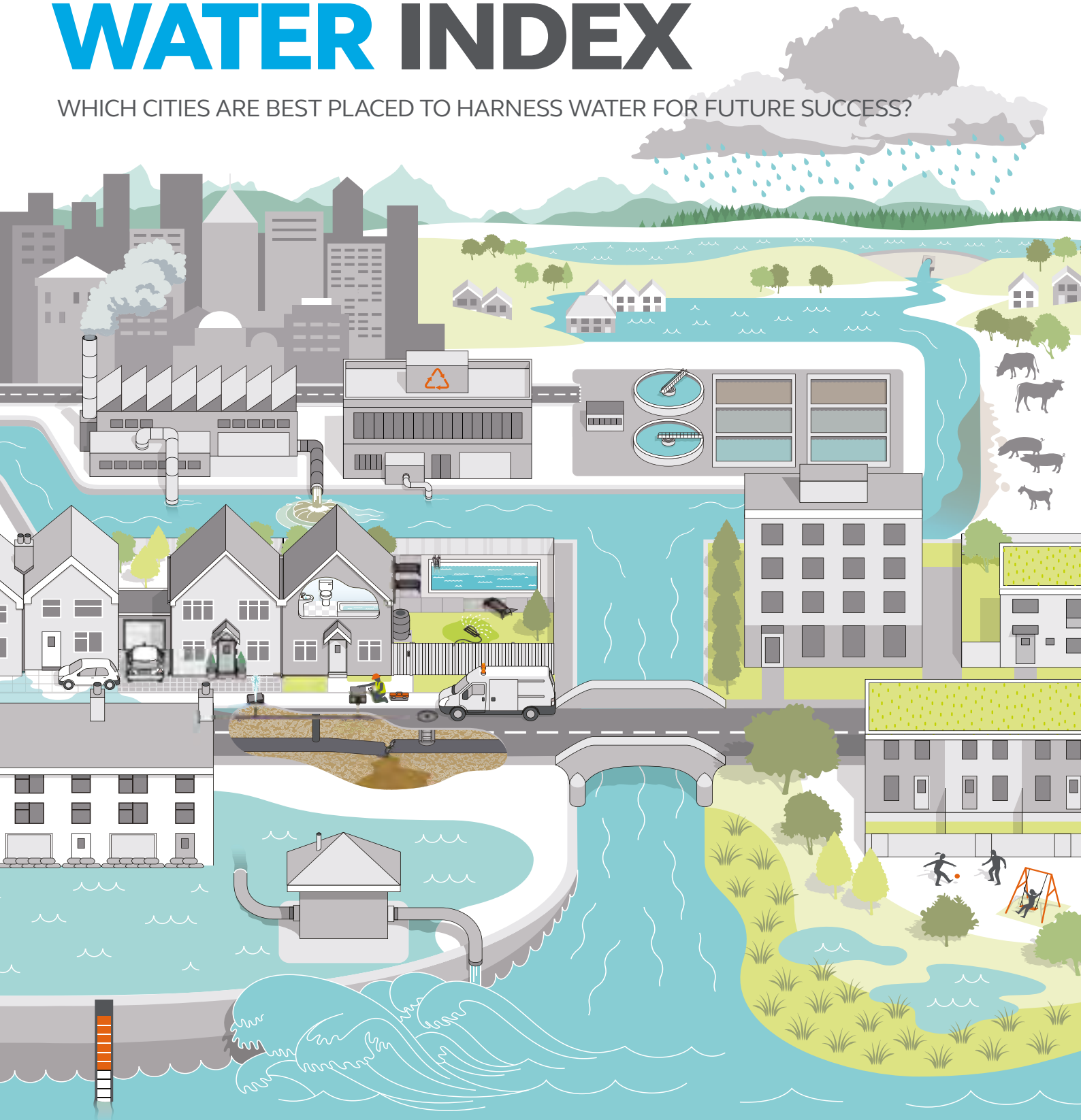


SUSTAINABLE CITIES **WATER INDEX**

WHICH CITIES ARE BEST PLACED TO HARNESS WATER FOR FUTURE SUCCESS?



1. FOREWORDS

CITIES: WATER HUBS

Great cities are defined and illuminated by the water that surrounds them or flows through them. Be it the harbors of New York, the river estuaries of London, the Amsterdam canals, the waterfronts of Doha or the beaches of Sydney, water is what gives a city its unique magnetism and attraction factor.

Cities are rarely spontaneous creations. They are often strategic settlements grounded by access to water and linked by transportation, trade and commerce. The historical positioning of cities proximate to fresh and navigable waters enabled settlements to flourish, grow and prosper. Now more than ever, cities, their waterscapes and water sources face challenges: water demand is rising, aquifers are being depleted and the threat of extreme weather is increasingly real.

The right balance is a tough one to strike; cities can be overburdened with too much water or stressed without enough. Urbanization causes further demand for drinking water as well as sanitation and the need for additional water sources, while increasing impermeable areas that can contribute to flooding. Cities are responsible for protecting their citizens from pollutants, disease and destructive storm surges. Many are struggling and many more are vulnerable.

Cities which carefully and creatively use their water assets for strategic urban advantage will ultimately be more livable, safe and competitive. Cities that are truly distinguished by a thriving relationship with their waterscape can make a huge contribution to the quality of life of their residents, attract tourism and investment. Hungarian physiologist and Nobel Prize winner Albert Szent-Gyorgyi famously said 'water, the hub of life'. So, too, cities are renowned for being hubs of knowledge, art and commerce that can further enrich and inspire as they leverage their position as water hubs.

The World Economic Forum named water crises as one of the top three highest global risks to economies, environments and people, in terms of impact in 2016. Water demand issues and climate change risks are happening right here and right now. The cities that best understand this and act first will be the ones that not only help save the planet from an impending water crisis, but will also be the first to attract investment and improve their competitive position.

This report seeks to expand on our annual Sustainable Cities Index to focus solely on water and identify which city is harnessing its water assets to its greatest long term advantage. It is our hope that city leaders find this ranking to be a valuable tool in helping them to think of water as an opportunity and as a resource for economic development while also meeting the critical needs and safety of their residents and the environment.

John Batten

Global Director of Water and Cities



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GUEST FOREWORD

SUSTAINABLE DEVELOPMENT FOR WATER WISE CITIES

Cities are continuously changing dynamic systems that bring together many strands of societies and economies. They are hubs of productivity, ideas, creativity, socio-economic development and, at their best, desired places for people to live and thrive. Today half of humanity lives in cities and this is set to grow to 80% in the decades to come. Most of the urbanization is happening rapidly in developing and emerging economies resulting in major pressures on fresh water supplies, used water collection and treatment, air and water quality and public health.

The global community has recognized this and captured it in the United Nation's Sustainable Development Goal 11 focusing on making cities inclusive, safe, resilient and sustainable. Agreed upon by governments around the world, this Sustainable Development Goal aims to, amongst other things, reduce the impact of (water related) disasters, reduce the environmental impact of cities and increase the universal access to green and public spaces. To achieve these objectives we have to put water at the center stage of urban development.

Water's role in sustainable development is further emphasized in Sustainable Development Goal 6: Ensuring safe access to water and sanitation for all. The focus here is on achieving universal and equitable access to safe and affordable drinking water as well as adequate and equitable sanitation and hygiene for all. This simultaneously aims to improve water quality by reducing pollution and halving current levels of untreated wastewater, while substantially increasing recycling and safe water reuse. In addition, governments have set the target to protect and restore water-related ecosystems including wetlands, rivers, lakes and aquifers.

These global goals form an ambitious agenda for city leaders to deliver progress on - without it the sustainable socio-economic development of cities is unlikely to happen. No two cities are alike or will follow the same development path. Exchange of experiences, know-how and expertise between cities plays a crucial role in learning and adapting to changing conditions.

The Sustainable Cities Water Index is an offering to foster such cooperation. Working with and making comparison between peer-cities creates the awareness, insight and foresight needed to build the sustainable and water wise cities of the future. It is by using such metrics that cities can show citizens and investors how their water resiliency, water efficiency and water quality makes them attractive and world class.

Dr. Ger Bergkamp

Executive Director, IWA – International Water Association



2. EXECUTIVE SUMMARY

- For centuries water has helped shape many of the world's greatest cities, be it as a source of drinking water, an access to trade routes or as a means of protection against attack.
- Water remains a critical strategic issue today as city leaders seek to balance the priorities of giving citizens and commerce access to clean water, disposing of wastewater, while also protecting them from the dangers of having too much through floods and extreme weather.
- The Arcadis Sustainable Cities Water Index assesses 50 global cities by the stewardship of their water across issues impacting their water resiliency, efficiency and quality to show which cities are best positioned to harness water for their long term success.
- The report finds that European cities lead the way on the overall sustainability of their water systems and management, holding seven of the top ten places, with Rotterdam, Copenhagen and Amsterdam taking the top three rankings. However the low placings of cities like London (21st) and Rome (28th) show that additional investment is needed elsewhere in Europe.
- In North America, Toronto (6th), Washington DC (13th) and New York (14th) perform well overall. Los Angeles ranks second for efficiency, while Chicago and Philadelphia rank second and third for quality. Overall, American cities show their vulnerability to natural disasters and extreme weather with seven U.S. cities in the bottom half for resiliency.
- Asian cities trail their western counterparts by some distance overall, with Singapore (22nd), Seoul (23rd), Tokyo (26th) and Hong Kong (30th) the highest ranked in the middle order of the Index. Poor sanitation and insufficient treatment of wastewater see many other Asia cities near the bottom such as New Delhi (50th) and Mumbai (49th). Manila (48th) ranks lowest for resiliency and quality.
- Dubai (32nd) is the highest ranked Middle Eastern city, but other cities rank lower due to the many water management challenges in the hot, desert climate.
- The Australian cities of Sydney (8th) and Melbourne (11th) score well thanks to efficient water systems and investment in desalination that creates better water conditions.
- Latin American cities feature in the bottom half of the Index too. Buenos Aires (33rd) is the highest placed, but Rio de Janeiro (44th) places near the bottom. New investment is needed to boost water quality, particularly in wastewater treatment and sanitation.
- The African cities of Johannesburg (45th) and Nairobi (46th) perform well when it comes to resiliency due to geographic advantage but are held back by inefficiency and poorer water quality.
- Overall, cities need to make greater investment to improve their resiliency to extreme weather events and unforeseen water shortages. In order to achieve long term viability, city leaders need to pay close attention to each area of water sustainability for it to be as much part of shaping their city's future as it was of its past.



3. CITIES WATER INDEX

3.1 WHAT DO WE MEAN BY WATER SUSTAINABILITY?

The way in which cities manage their water has a lot to do with their ability to attract and retain businesses and residents, to encourage economic growth, and to compete on the global stage. Top cities understand and address their water in a sustainable manner. This means efficiently providing safe, reliable, and easily accessible water to residents and businesses; reliable access to sanitation, and protecting waterways from pollution. It also means being resilient and adaptable to extreme weather events and climate change that may contribute to issues such as flooding and scarcity.

Each of the 50 cities included in this Index have distinctive water relationships that helped shape their urban character and define their commercial identity and competitiveness. In order to analyze their management of water and whether it is sustainable, this report breaks down water sustainability into three core elements:

FIG 1. THREE ELEMENTS TO A SUSTAINABLE WATER FUTURE



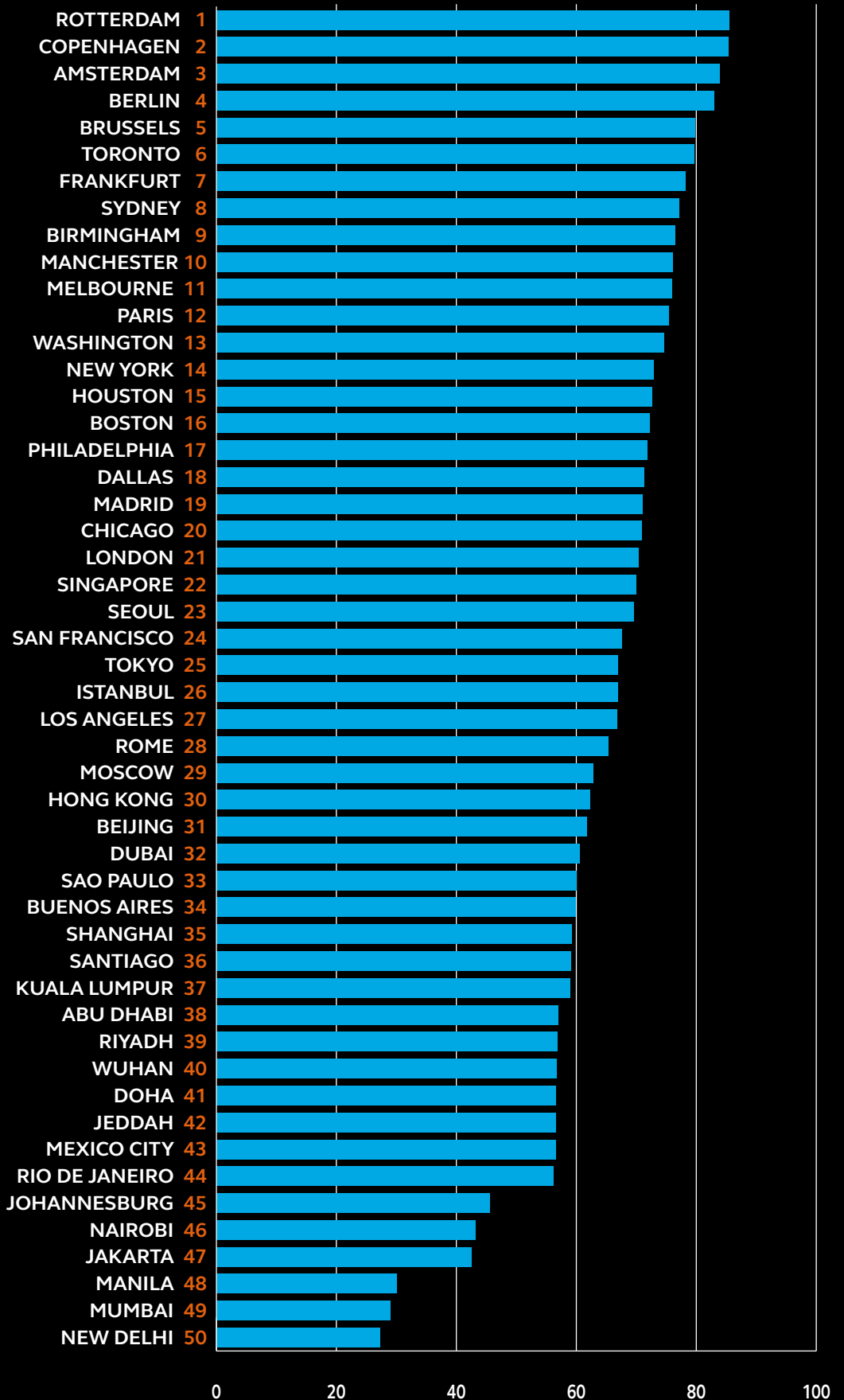
This Index was prepared in partnership with the Centre for Economics and Business Research (CEBR) and gauges the sustainability of city waterscapes overall, as well as focusing on each sub-index measure as well. **The Index is not intended to be a “report card” on how well municipal water utilities do their jobs nor is it a verdict of a city’s achievement. It is a tool to help inform future improvement and long term water sustainability.**

3.2 OVERALL RANKINGS

THE WORLD'S MOST SUSTAINABLE CITIES FOR WATER

The overall Index examines the water sustainability of 50 cities from 31 countries across all continents of the world. Cities are ranked according to not only how sustainably they manage and maintain water, but also against their natural risk and vulnerability across three pillars of water sustainability – resiliency, efficiency and quality.

FIG 2: SUSTAINABLE CITIES – WATER INDEX OVERALL



EUROPEAN CITIES LEAD THE WAY

European cities dominate the overall rankings, taking seven of the top ten places. Many of these cities have mature water systems that have been built up over a long period of time, many times in response to challenges they have faced with water. The Dutch cities of Rotterdam and Amsterdam, for example, place at first and third respectively, having overcome challenges such as flooding in the last century.

In general, European cities have high water quality through well-established drinking water supply, sanitation and wastewater treatment systems. It is in the area of efficiency that some European cities are challenged. London, at 21st, is behind fellow UK cities Birmingham (9th) and Manchester (11th).

Berlin (4th) is amongst the most consistent overall performing cities across all categories. The German capital is also one of the most resilient cities in the world due, in part, to its low susceptibility to natural disasters.

NORTH AMERICA – THE EAST COAST PERFORMS HIGHER THAN THE WEST

No U.S. city makes it into the Index's overall top ten, with the East Coast hubs of Washington DC (13th) and New York (14th) performing significantly better than their West Coast counterparts. Cities in California are hampered mainly by their vulnerabilities to resiliency, such as a higher susceptibility to drought and natural disasters.

ASIA-PACIFIC – A MIXED PICTURE

It is a rather mixed picture for Asian cities when it comes to water sustainability. Four emerging

economy cities - Jakarta (47th), Manila (48th), Mumbai (49th) and New Delhi (50th) finish out the overall ranking, others in Asia fair better.

Tokyo (26th overall) has one of the best efficiency scores in the world despite lack of wastewater reuse, reserve water and greenspace. Furthermore, Singapore (22nd) does well with the elements over which it has control such as leakage, treatment and metering, despite its geographic vulnerability regarding flood risk and water reserves.

The Australian cities of Sydney (8th) and Melbourne (11th) score well thanks to investment in efficient water systems and desalination creating better future water conditions.

LATIN AMERICA - UNDERPERFORMING

Latin American cities underperform when it comes to their overall water sustainability with each location featuring relatively low in the Index due to geographic vulnerabilities to flooding and drought as well as lack of investment.

Efficiency is a particular issue for Buenos Aires (33rd). The Argentinian capital has the lowest instance of water metering in the Index despite its issues with leakage due to aging water infrastructure. Mexico City (43rd) performs better than most Latin American cities for efficiency due, in part, to its water charges.

MIDDLE EAST – GEOGRAPHICALLY CHALLENGED

Due to its arid climate Middle East Cities face unique challenges, even the regional powerhouses of Dubai (32nd) and Doha (42nd) featuring in the lower end of the overall Index.





CITY PROFILE: ROTTERDAM

Overall ranking: 1 Resiliency: 1 Efficiency: 15 Quality: 16

As the highest ranking city in this Index, Rotterdam has the best balance among the three indices. It is in many ways a leading global city in urban resiliency and sustainability.

The city has been innovative and proactive in its approach to water resiliency; implementing a Chief Resilience Officer and works on implementation of the Rotterdam Adaptation Strategy. Driving global best practices on resiliency, the city shares its knowledge with other cities in the Connecting Delta Cities program of the C40, as well as in the Rotterdam Center for Resilient Delta Cities, and is visited by numerous water-oriented delegations all year round.

Some of the features that Rotterdam is particularly proud of include its floating water pavilion, multifunctional flood protection, the water plaza and water storages under the central station and Museum Park Garage.

Additionally, with heavy investment in its reservoir catchment system, Rotterdam is among the highest in the world in water reserves. Lead by Evides, a world-leading water utility committed to sustainable water practices, Rotterdam is working on large-scale water reuse for industrial wastewater, which could further improve future sub-rankings and ensure greater sustainability as reuse is statistically an indicator for Rotterdam that is slightly below other indicators.



CITY PROFILE: BOSTON

Overall ranking: 16 Resiliency: 30 Efficiency: 19 Quality: 6

Boston, for a long period of its history, experienced water quality issues in Boston Harbor as it grew due to the discharge of raw sewage and its status as a major port. In recent decades the water quality has significantly improved, and Boston Harbor, as well as the Charles River and other water bodies, have been transformed.

Since the creation of the Massachusetts Water Resources Authority in 1985, the city has invested billions on wastewater treatment through creation of facilities such as a new Deer Island Treatment Plant, increasing the reliability and volume of wastewater treatment, while at the same time reducing combined sewer overflows.

Rates of water treatment, waterborne diseases, and coverage for drinking water and sanitation are in line with other developed cities, due to investment in the high quality reservoirs and water treatment. Resiliency ranked low relative to the other two indicators, particularly with respect to green space and flood risk. However, Climate Ready Boston aims to reduce vulnerability to climate change impacts.



CITY PROFILE: SINGAPORE

Overall ranking: 22 Resiliency: 24 Efficiency: 13 Quality: 31

Singapore, the top ranking Asian city in this Index, has made vast improvement over the past several decades to become a regional water hub.

Where Singapore has control – that is, treatment, universal coverage, metering, wastewater reuse, and leakage, it receives high marks. However, it does not have control over its physical location, which leaves it vulnerable to flood risk and naturally dependent on foreign freshwater sources. However even on these fronts Singapore has invested, as exemplified by projects such as the Marina Bay and the evaluation of diversified storage options such as sub-terrain caverns upon recognition of their limited storage options.

Under the leadership of PUB, the nation’s utility, the island nation has gone from one extremely vulnerable to an innovator in many areas. PUB has also overcome many negative public perceptions of potable water reuse, allowing them to provide high quality water to consumers via reuse. Pre-treatment, the source water is highly polluted, as urban runoff is exposed to many manmade sources of phosphorus and sediment leading to urban runoff challenges alongside others such as water stress and reserve water.

Singapore is a water-stressed country-city. Water dominates its security policies with Singapore adopting a ‘close the water loop’ strategy: maximize yield ‘collect every drop’, reuse endlessly and drink seawater.



CITY PROFILE: SYDNEY

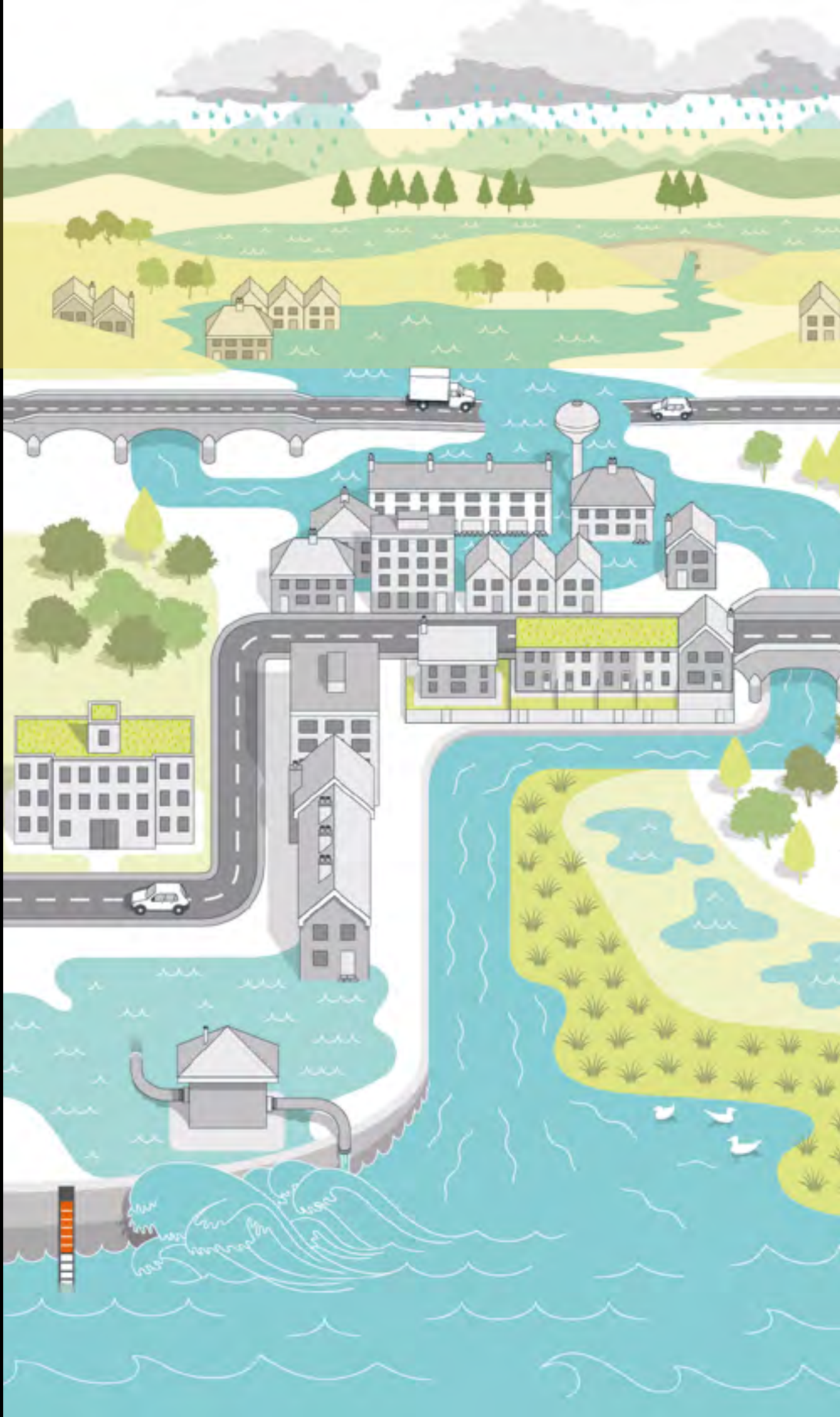
Overall ranking: 8 Resiliency: 13 Efficiency: 4 Quality: 25

Located on Australia’s East Coast, Sydney surrounds the world’s largest natural harbor and has a number of tributaries and waterways associated with it. The world famous Sydney Harbor Bridge and iconic Sydney Opera House are both clearly identified side by side to their water surroundings.

Sydney is committed to diversifying its water portfolio through efforts such as desalination and asset management. Billions of dollars in investment in desalination works to secure the supply against climate change. Sydney has a Chief Resiliency Officer as it is susceptible to natural disasters and is committed to ensuring a sustainable water supply. The city experiences moderate water stress, however their water reserves are higher compared to most of the Indexed cities, as is their green space.



RESILIENCY:
Withstanding
natural disasters
and unforeseen
shortages





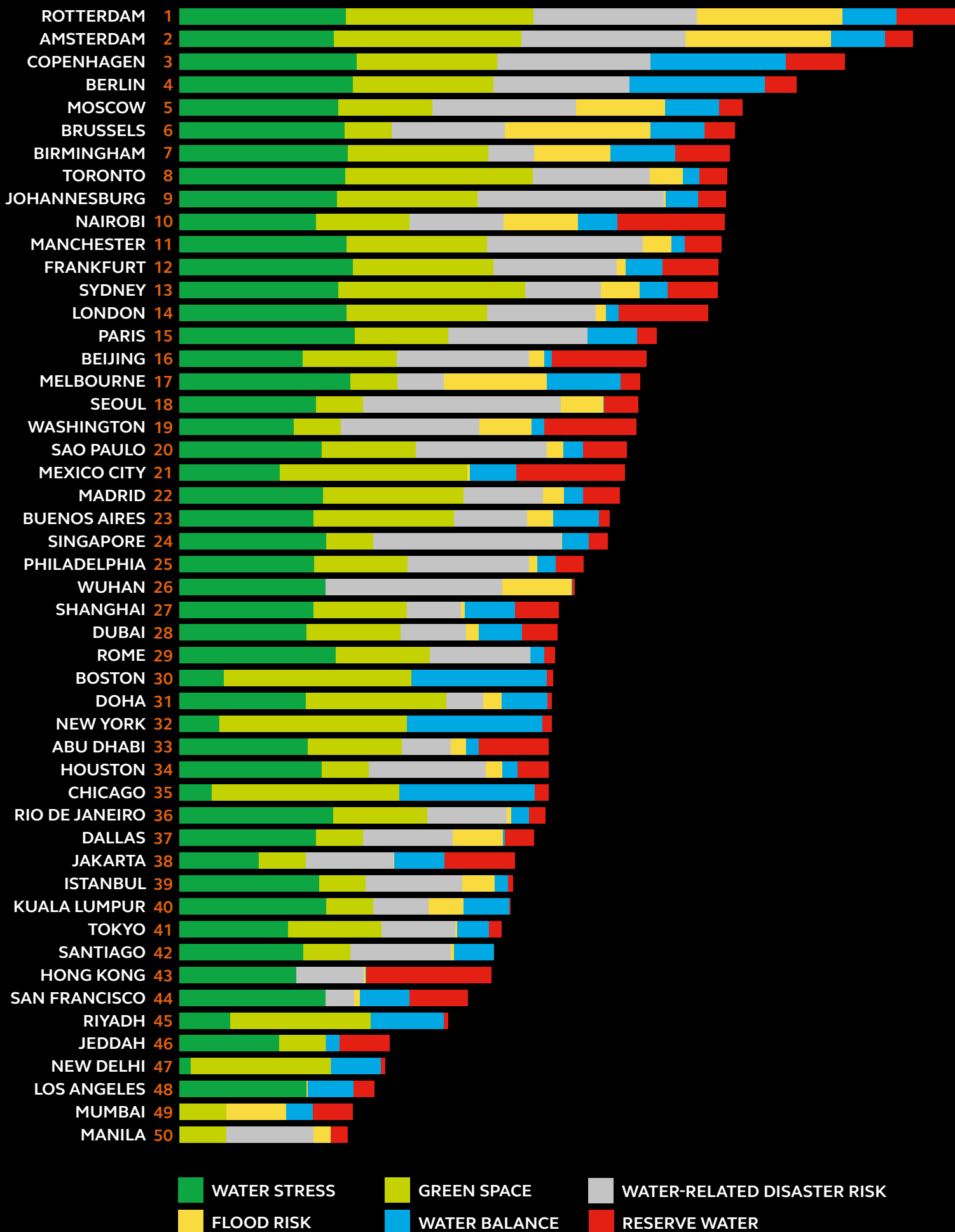
3.3 WATER

RESILIENCY SUB INDEX

A water resilient city is well prepared to overcome the challenges associated with both too little as well as too much water. It protects its citizens against disasters such as flooding and drought, while ensuring that water-related services continue uninterrupted. Even in the face of crises, a water resilient city should be adapted to recover quickly.

As a result of climate change, soil subsidence, coastal erosion and urbanization, extreme weather events and water scarcity are becoming more commonplace in many cities, particularly those located in coastal or riverine areas. Furthermore, the Index highlights a significant gap between the top performers and the rest of the world. Floods, sea level rise and coastal erosion risks are just some of the growing concerns to many of these lower performing cities.

FIG 3: ROTTERDAM TOPS THE RESILIENCY SUB-INDEX RANKING



Rotterdam and Amsterdam, although both below sea level, are the top two performers on the water resiliency sub-index. These locations are well known for their excellent water management and robust flood protection practices. The Netherlands maintains a continuous investment program in dikes, dunes and flood barriers, thus being considered the safest delta on Earth.

The presence of parks and green space – creating stormwater storage capacity and helping to battle the urban heat island effect – helps make cities more resilient. Therefore, the lack of green space impacts many major Middle Eastern and Asian cities such as Tokyo, Shanghai, Dubai and Doha.

Los Angeles' low ratings for reserve water, as it draws 85% of its drinking water supplies from sources hundreds of miles away in northern California and the Colorado River, and water stress, contribute to its lower ranking in resiliency as the region is susceptible to drought and is geographically vulnerable to natural disasters. In a broader sense, some U.S. cities' lack of green space impacts their resiliency. U.S. cities also score lower than most European cities on flood risks given their lower protection standards.

Unsustainable levels of extraction from scarce groundwater sources lead to severe water stress, explaining the presence of desert cities like Jeddah and Riyadh at the lower end of the resiliency rankings. The vulnerability of some of the Pacific Rim cities such as Manila, Jakarta, and Hong Kong to major storms and floods is reflected in the ranking.



CITY PROFILE: DALLAS

OVERALL RANKING: 18 RESILIENCY: 37 EFFICIENCY: 18 QUALITY: 11

Dallas is unique in that it is susceptible to not only floods along the Trinity River basin, but also drought. Both these issues provide serious consequences for the city's infrastructure, residents and businesses. The city has invested heavily in the construction of reservoirs due to high demand brought on by increased urbanization. Dallas outranks its regional counterparts for reservoirs in the city's vicinity and promoting improved conservation by adopting an irrigation ordinance which included time-of-day watering restrictions. The city's water reuse ranks below the Californian cities in the Index which has impacted its resiliency rating.



CITY PROFILE: NEW YORK

Overall ranking: 14 Resiliency: 32 Efficiency: 14 Quality: 7

New York City demonstrates strengths with respect to low levels of water pollution, non-revenue water, drinking water and sanitation. Extensive pretreatment and source control programs, reductions in combined sewer overflows, as well as reduction of nitrogen discharges to Western Long Island Sound and portions of Jamaica Bay via the Nitrogen Control Program have led improving water quality over the years. The primary source of drinking water is the Catskill/Delaware water supply, which is of such high quality that New York City is one of only five large cities in the U.S. with a surface water supply not requiring filtration. However, like many other U.S. cities, the City's per capita water consumption rates are higher than other comparable large metropolises outside of the U.S. and it does not reuse significant amounts of treated wastewater.



CASE STUDY: PREPARING NEW YORK FOR A RESILIENT FUTURE

Further, the city was recognized to be vulnerable to flooding and other climate change impacts, particularly in the aftermath of Superstorm Sandy. Sandy was the second costliest hurricane in United States history. Manhattan's economy endured devastating effects during and after the storm; The New York Stock Exchange closed for a week, neighborhoods and businesses were ruined and transportation systems, such as parts of the subway, flooded. The shocking effects brought to the forefront New York's vulnerability to coastal flooding on its unprotected coastline and its need for resilience. It is estimated that if no action is taken, New York will incur at least \$500 million in damages over the next 50 years accompanied by ripple effects across the global economy.

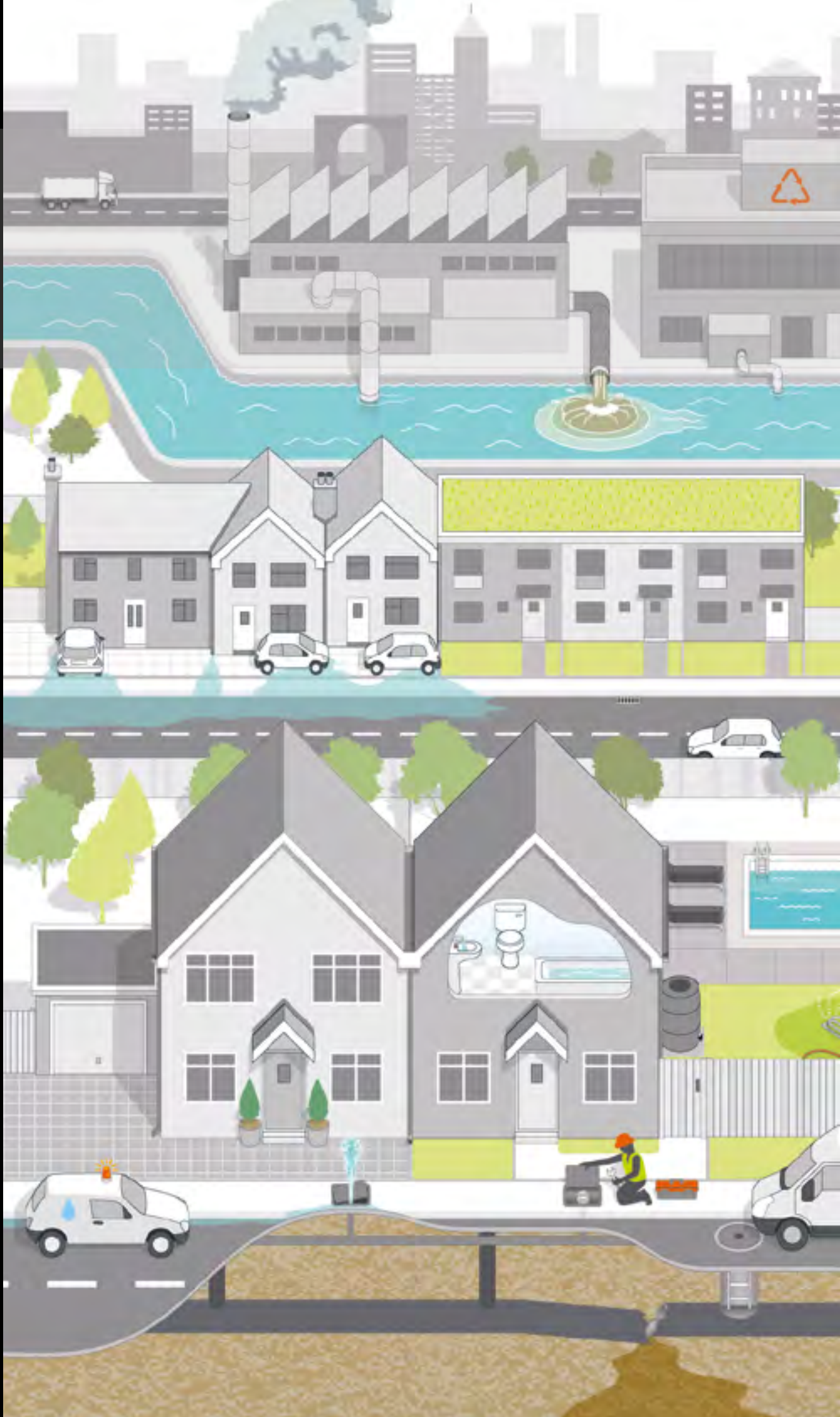
In response to the storm, the U.S. Department of Housing and Urban Development (HUD) launched a competition, Rebuild by Design, to bring together the best and brightest ideas to protect the Northeast United States from the next big storm. Along with the Bjarke Ingels Group (BIG), Arcadis and partners were the selected to design resilient infrastructure in New York City.

The winning solution, 'The Big U' aka the Dryline, envisioned a protective system around Manhattan to protect the millions who live, work and visit there.

The East Side Coastal Resiliency project is the first step to realizing the vision of the Big U and a resilient New York City. Arcadis and partners developed feasibility and conceptual design reports to provide flood protection and social infrastructure for 200,000 residents and 21,000 business in the area. A range of multifunctional resiliency solutions integrated with neighborhood and community amenities improve community access and expand enjoyment of parks and recreational spaces.

The results are groundbreaking and highly acclaimed: the Big U will increase resilience and protection for residents of the Big Apple and present significant cost savings for the city.

EFFICIENCY:
Effectively
managing
the water
supply



A vertical illustration on the left side of the page depicts various urban and water-related elements. At the top, a grey city skyline is visible. Below it, a blue body of water with white waves is shown. Further down, there are stylized buildings in shades of green and grey. A road with a dashed white line and green trees is depicted. Below the road, a blue rectangular area represents a water reservoir or pool. At the bottom, a white utility van with a black wheel and a black roof rack is shown on a road. The entire illustration is set against a light background.

3.4 WATER

EFFICIENCY

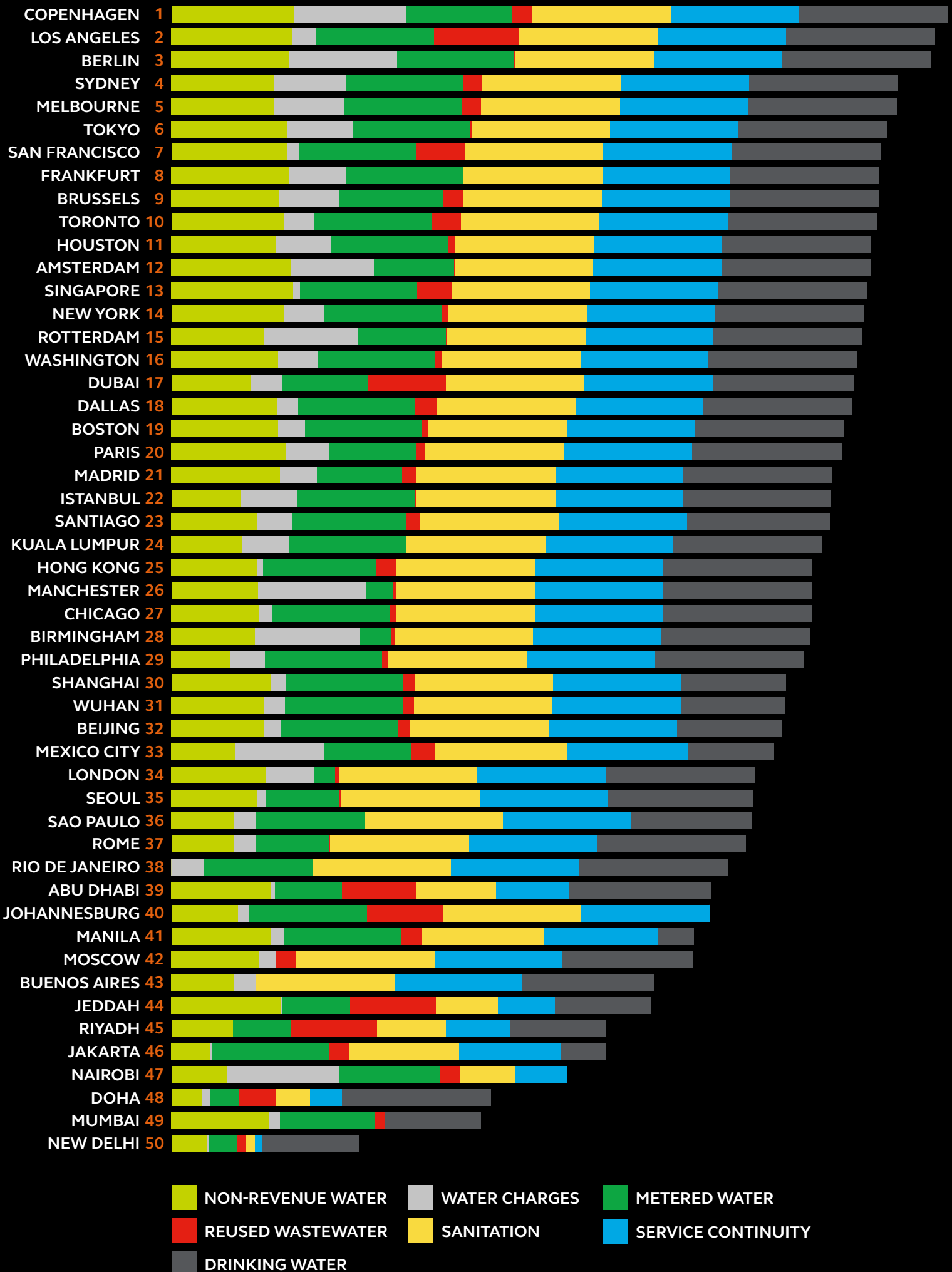
SUB INDEX

HOW EFFECTIVE ARE THE WORLD'S CITIES AT MANAGING THEIR WATER SUPPLIES?

Clean, usable water is an extremely valuable resource that is essential to the health of a city's citizens and economy. Efficient and controlled management of this resource is, therefore, vital for service continuity in both the production and distribution of water, minimizing cost of service, and preserving this resource for future generations. An often-faced dilemma is how to balance charging customers for the true value of water while maintaining affordability. Higher rates encourage water conservation and reuse, and can positively impact efficiency by encouraging investment in infrastructure improvements; but it can also be cost prohibitive.

Low instances of leakage, as well as accountability in terms of water usage in the form of metering, are key to ensuring a city's water systems run efficiently. In many developed economy cities, much of the infrastructure is well past its useful life and the cities have seen the effectiveness of their systems suffer, with an increase in pipe leakage and service interruptions due to infrastructure failure. In many emerging economy cities, metering is relatively rare, and instances of non-revenue water and service interruptions relatively high.

FIG 4: COPENHAGEN RANKS FIRST FOR EFFICIENCY, WITH LA IN SECOND



In the efficiency sub-Index Copenhagen tops the list. The Danish capital has one of the lowest rates of leakage in the world, fairly high charges per unit of water and a high incidence of water metering. Amsterdam and Rotterdam, cities that top the resiliency rankings, rank 12th and 15th respectively in efficiency. Reuse of wastewater is the weak spot in these cities.

On efficiency, the UK cities rate relatively low. All three cities sit behind some developing economy cities due to low levels of reused wastewater and lack of water meters. While underperforming in other areas, Tokyo has one of the highest efficiency scores of the cities studied due, in part, to its comparatively modern infrastructure which keeps leakage rates low.

Los Angeles and San Francisco boast high levels of water reuse. This is a growing trend across states that are experiencing water scarcity. To date reuse has primarily been for agricultural and industrial purposes, however, potable reuse applications are increasing and gaining interest.

In the Middle East, desert cities such as Abu Dhabi, Jeddah and Riyadh also possess high scores in terms of reuse, while they do score lower on other aspects of efficiency.

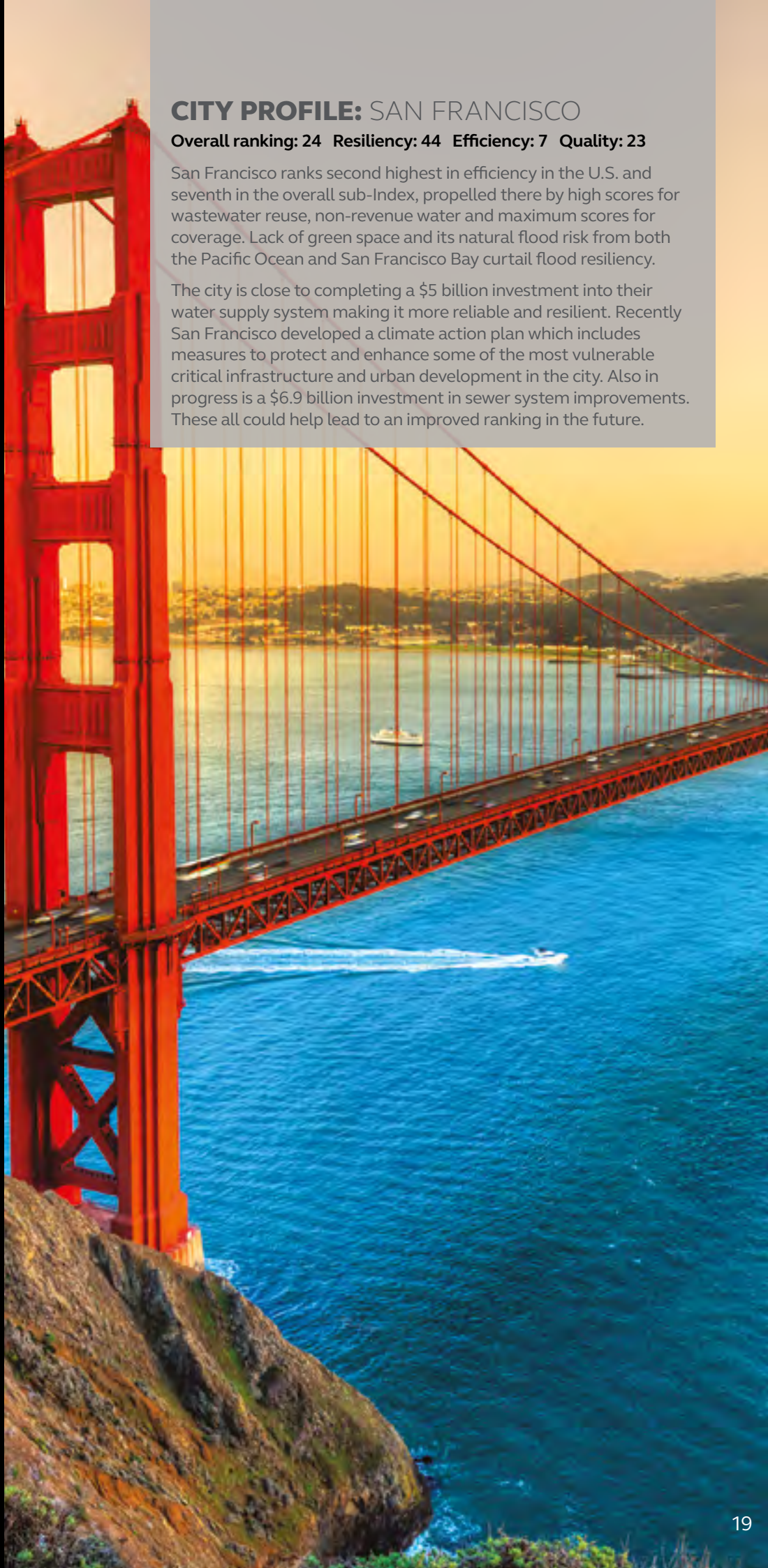
Sydney performs strongly when it comes to ensuring its systems and infrastructure deliver effectively for its citizens and businesses. An increase in wastewater reuse would see Australia's most populous city perform even higher with respect to efficiency.

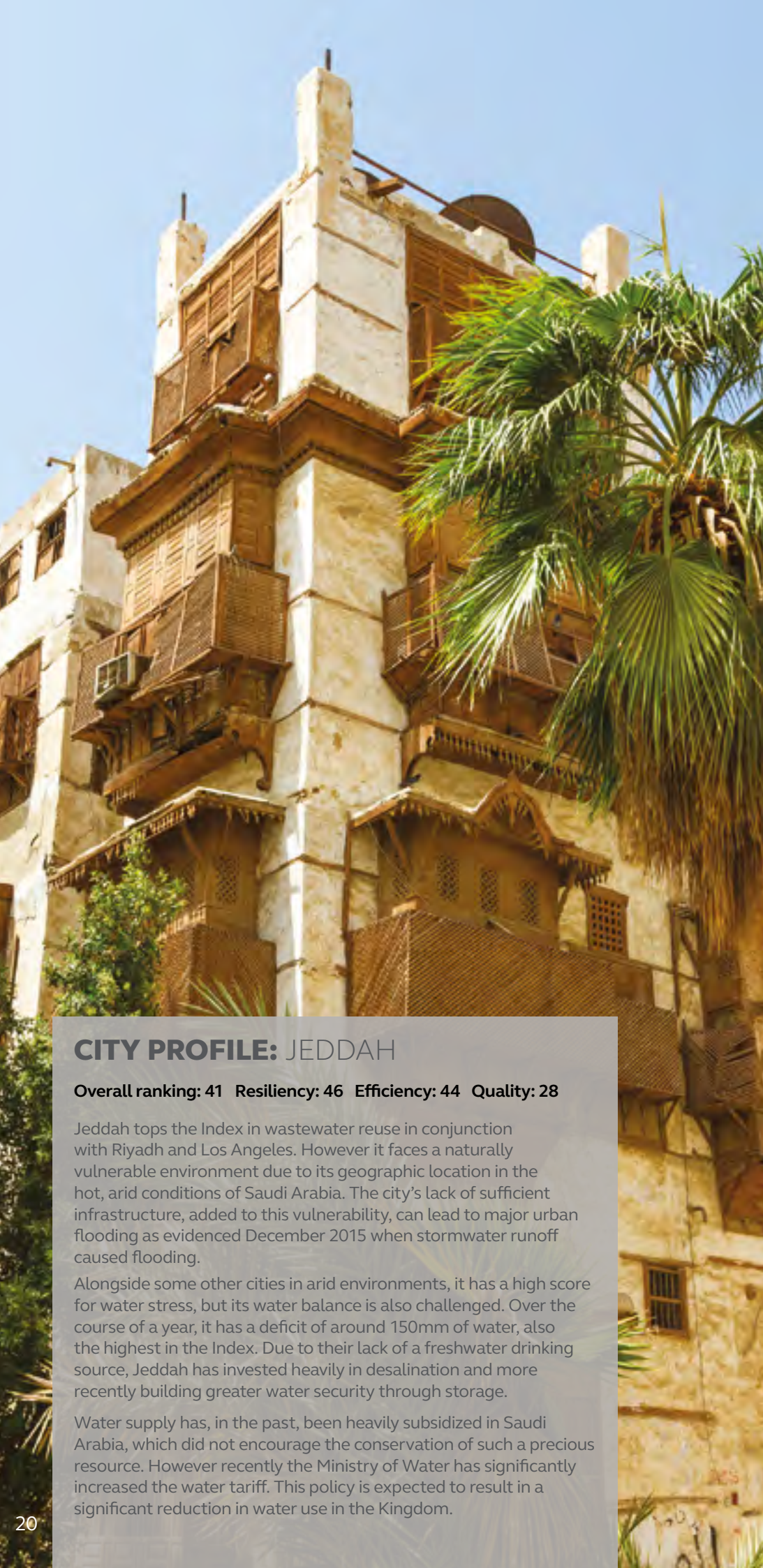
CITY PROFILE: SAN FRANCISCO

Overall ranking: 24 Resiliency: 44 Efficiency: 7 Quality: 23

San Francisco ranks second highest in efficiency in the U.S. and seventh in the overall sub-Index, propelled there by high scores for wastewater reuse, non-revenue water and maximum scores for coverage. Lack of green space and its natural flood risk from both the Pacific Ocean and San Francisco Bay curtail flood resiliency.

The city is close to completing a \$5 billion investment into their water supply system making it more reliable and resilient. Recently San Francisco developed a climate action plan which includes measures to protect and enhance some of the most vulnerable critical infrastructure and urban development in the city. Also in progress is a \$6.9 billion investment in sewer system improvements. These all could help lead to an improved ranking in the future.





CITY PROFILE: JEDDAH

Overall ranking: 41 Resiliency: 46 Efficiency: 44 Quality: 28

Jeddah tops the Index in wastewater reuse in conjunction with Riyadh and Los Angeles. However it faces a naturally vulnerable environment due to its geographic location in the hot, arid conditions of Saudi Arabia. The city's lack of sufficient infrastructure, added to this vulnerability, can lead to major urban flooding as evidenced December 2015 when stormwater runoff caused flooding.

Alongside some other cities in arid environments, it has a high score for water stress, but its water balance is also challenged. Over the course of a year, it has a deficit of around 150mm of water, also the highest in the Index. Due to their lack of a freshwater drinking source, Jeddah has invested heavily in desalination and more recently building greater water security through storage.

Water supply has, in the past, been heavily subsidized in Saudi Arabia, which did not encourage the conservation of such a precious resource. However recently the Ministry of Water has significantly increased the water tariff. This policy is expected to result in a significant reduction in water use in the Kingdom.

CASE STUDY: A SECURE FUTURE FOR DOHA'S WATER

Between now and 2030, the number of people living in Qatar is expected to increase by almost a quarter to 2.3 million. It has also become a tourist destination and will host the 2022 FIFA World Cup. Rapid demographic and economic changes heighten the need for improved efficiency and capacity of their public services such as power and water, with desalination plants being the country's main source of drinking water. Recognizing the challenge of meeting the growing demand for water with increased efficiency, the country recognized the need for a national strategic plan to safeguard its future.

With just under two days worth of water in the system at any given time, any disaster – be it natural or manmade – would have the potential to create serious problems in Doha. KAHRAMAA, the Qatar General Electricity and Water Corporation, is therefore increasing water storage and security, as well as their efficiency through an ambitious mega reservoir project. Five interconnected sites, each containing four-to-five reservoirs, are currently under construction and are on course to be delivered by 2018. Additionally, an expansion to nine reservoirs at each site is planned to be delivered by 2036, improving efficiency and storage in Qatar's water system even further.

Each reservoir site will be connected directly to the existing water transmission system. This allows the bulk storage to be held in close proximity to where demand will be, while also making sure the water in circulation continues to comply with World Health Organization standards. Qatar's mega reservoirs will be the largest of their kind in the world. With seven full days of water security, Doha's people and businesses will have an efficient, secure and flexible supply for its future.



QUALITY:
Providing a
clean and
healthy water
supply





3.5 WATER

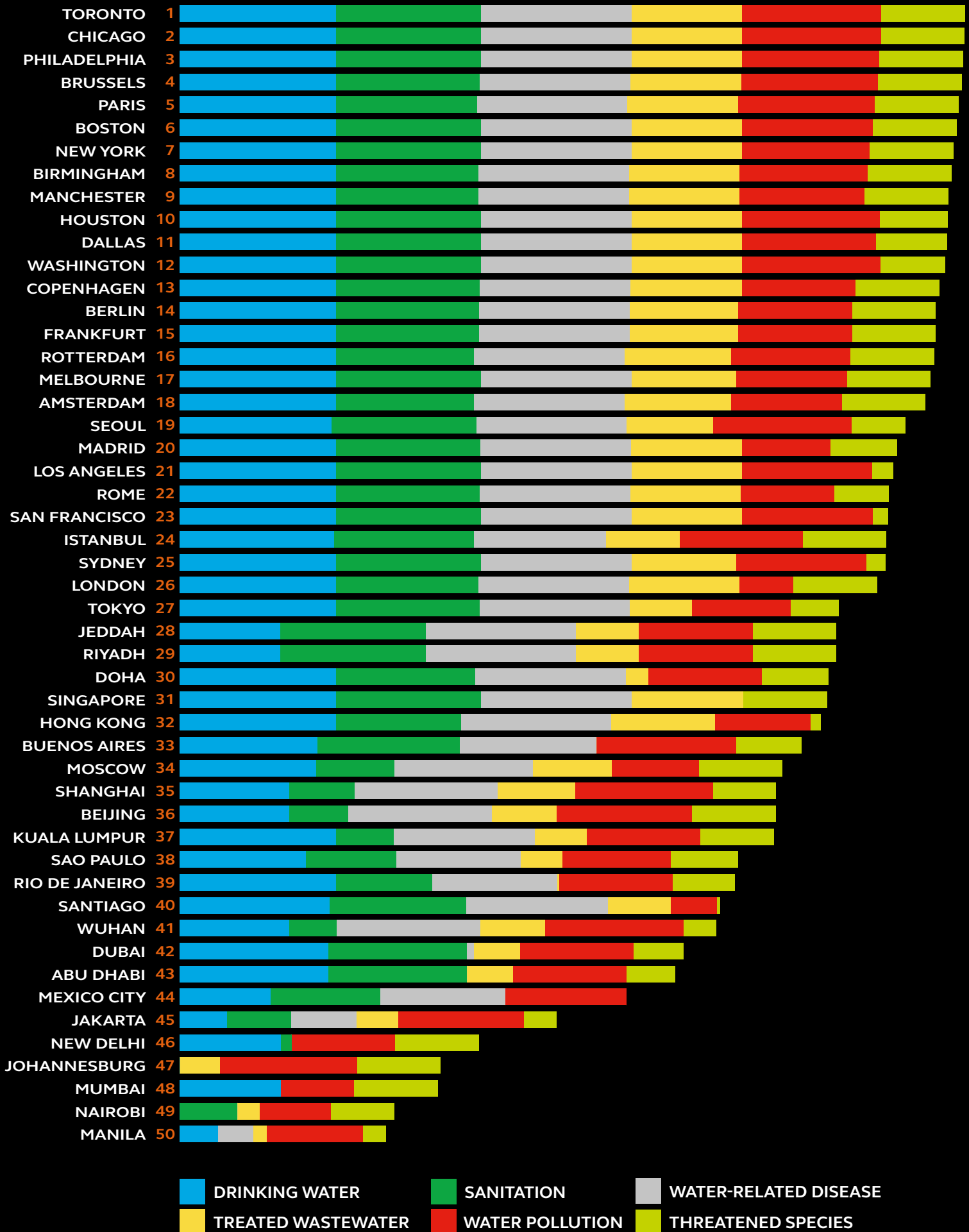
QUALITY SUB INDEX

TO WHAT EXTENT DO THE WORLD'S CITIES PROVIDE A CLEAN AND HEALTHY WATER SUPPLY?

In the Index, water quality is arguably the area where performance is highest, with many cities having recognized their critical role in improving quality of life, and thus have made significant investment. However, it remains a challenge for a number of developing cities such as growing cities in Africa and Asia. According to a recent UN report, ten percent of the world's population still does not have access to safe drinking water.

Cities in the developed world have historically improved their prosperity and economies only after adequately addressing water quality and sanitation, making them more competitive. Cities in developing nations will need to improve water quality to become prosperous, sustainable urban centers. Unsafe water and lack of sanitation is a major contributor to illness and disease, and lack of accessible and reliable source of potable water can minimize productivity and deter business investment. Polluted waterways restrict recreational activities, make clean up costly and deter livability.

FIG 5: TORONTO COMES TOP FOR WATER QUALITY



■ DRINKING WATER ■ SANITATION ■ WATER-RELATED DISEASE
■ TREATED WASTEWATER ■ WATER POLLUTION ■ THREATENED SPECIES

Generally, developed nation cities achieve very close to a maximum score for water quality. When it comes to the categories of drinking water coverage, water treatment, sanitation and low incidences of water-related diseases, locations in the developed world perform well enough to sustain a growing economy. That said, scores drop off quickly towards the bottom of the Index, below a certain developmental threshold. The main statistical differentiator between the cities in developed economies is the level of threatened species and, to a lesser extent, water source pollution. Inadequate access to sanitation and treatment of wastewater are the primary issues for many of the cities located toward the latter of the quality rankings.

Toronto scores highest on the water quality Index, largely as a result of it having the lowest levels of water pollution at its source. Hong Kong performs well when it comes to access to drinking water and incidence of water related disease. However, a relatively higher level of threatened species when compared to other cities due in part to the upstream pollution of the Pearl River Delta.

Although drinking water and sanitation are good in Dubai, levels of threatened species and instances of water-related disease in the UAE overall see it perform behind the rest of the world.

Due to their low access to safe drinking water, poor levels of sanitation and low levels of wastewater treatment, the Index finds Manila and Nairobi rounding out the quality ranking.

The Brazilian cities of São Paulo and Rio de Janeiro rank relatively low on water quality, especially due to a low score on treated wastewater.

CITY PROFILE: CHICAGO

Overall: 20 Resiliency: 35 Efficiency: 27 Quality: 2

For quality, Chicago is one of the highest ranked cities because the historic decision to reverse the flow of the Chicago River to protect the quality of Lake Michigan. The city's TARP, or tunnel and reservoir program, invests and manages the city's critical infrastructure to handle combined sewer overflows. Thus, very little sewer effluent or pollution flows into its water bodies, creating sustainable water quality for the city. Chicago is close to having almost no pollution in their freshwater sources.

The city's efficiency vulnerability is being addressed through one of the most ambitious infrastructure replacement programs on their water and sewer lines, replacing 100 miles per year.

To further increase efficiency and reduce consumption, the Chicago Department of Water Management has a volunteer metering program, heavily incentivizing consumers with rate guarantees to increase awareness and reduce leakage. Chicago has also developed an incentive program that encourages developers to incorporate green roofs on new buildings, known as the Green Permit Program. Additional benefits of the Green Roof program for the city include mitigation of climate change through reduced need for heating and cooling in buildings with green roofs and an enhancement of the image of the city.



CASE STUDY: TRANSFORMING THE RIO TIETÊ – INVESTING TO IMPROVE WATER QUALITY

For centuries Rio Tietê in São Paulo facilitated trade, exploration and leisure activities. These activities were ultimately banned due to pollution in the river, mostly as a result of industrial waste.

The majority of the decline of the health and quality of the river occurred between 1940 and 1970 during a period of rapid urbanization and industrialization. Most of the waste from industries and sewage was conveyed into the Rio Tietê at a rate of approximately 134 tons per day. Population growth in São Paulo also led to illegal occupation of land and a subsequent increase in the amount of untreated sewage finding its way into the river.

NGOs and the media joined a nationally-led social campaign to clean up the river in the early 1990s. A petition attracted 1.2 million signatures, prompting the launch of Projeto Rio Tietê by the São Paulo State Government to clean up the river. Set into four stages over 25 years, the total investment is a projected \$5 billion USD. Once complete, the infrastructure will be able to safely treat the sewage generated by 19 million residents and significantly improve the health and quality of the river.

Since the first stage of the project, Arcadis has been the consultant and technical advisor to the company behind the project, Sabesp (São Paulo State Sanitation Company). Now in the third stage, as head of the consortium, Arcadis is helping Sabesp deliver the infrastructure to improve the quality of the water by connecting an additional 200,000 households to the sewer system and increasing the volume of sewage treated from 66% to 84%.

Projeto Rio Tietê has successfully endured through a backdrop of hyperinflation, financial crises and changes in the political landscape. Sabesp is now planning the fourth stage of the project which aims to increase sewage collection of 19 million inhabitants to 100% by 2024. Projeto Rio Tietê is a vital step for improving the quality of life in for every resident in the city and sets the stage for a sustainable future.

CITY PROFILE: SÃO PAULO

Overall ranking: 34 Resiliency: 20 Efficiency: 36 Quality: 38

São Paulo is one of the best performing cities in Latin America and tops resiliency in the region. This mega city is vulnerable to flooding and drought which poses substantial challenges to the city to manage the extremes. Irregular urban settlements and insufficient housing programs contribute to the low quality of the city's water bodies and the flood intensity.

São Paulo has invested in three key actions to provide regular water supply: a water loss reduction program, social education initiatives on rational water use and additional water supplies. These actions are now helping to progress the city's supply and quality. Even so, continued investment in more treatment plants and water reuse should be added as the largest potential points to increase São Paulo's position in the worldwide ranking around water sustainability.





4. HOW CITIES CAN SUSTAINABLY HARNESS THEIR WATER ASSETS FOR LONG TERM SUCCESS

4.1 WHAT ARE THE WATER CHALLENGES FACING CITIES TODAY?

All cities are facing water challenges they are not fully equipped to address. From urbanization to climate change and aging infrastructure to water security, cities must identify and prioritize short and long term initiatives to sustain or garner a competitive advantage through water. The key challenges faced are explored below.

RAPID URBANIZATION

All citizens want the same thing; a livelihood, a place to live, protection from disaster and, of course, drinking water and sanitation. Population growth can overwhelm water infrastructure. This, in turn, can result in increased demand, service interruptions, insufficient treatment, infrastructure failure, and high costs associated with the repair, replacement and expansion of infrastructure.

African cities like Johannesburg and Nairobi are dealing with considerable challenges related to rapid urbanization and its impact on almost every aspect of water sustainability. Growing Asian cities like Shanghai, with just 2 million inhabitants in 1920 and 23 million inhabitants today, are struggling with the impacts of growing population on the water ecosystem and its threatened species.

WATER SCARCITY

Water scarcity relates to the lack of safe and/or easily accessible water supplies impacting a city's competitiveness. Water scarcity is further aggravated by climate change often triggering persistent drought. Water is a driving factor for businesses, while scarcity of this resource limits a city's ability to grow.

Limited access to clean and safe water resources can lead to food shortages, economic slowdown and even political conflicts that can further exacerbate the economic and competitive position of the affected city. Water scarcity is a growing problem in cities with vulnerable climates, limited natural water resources and growing demand. All these elements are featured in the rapidly expanding desert city of Doha, resulting in limited water resources. The upcoming 2022 FIFA World Cup is likely to add to Doha's challenges with mass tourism likely to increase water demand. The California water crisis has also been widely reported, which has led to cities, like Los Angeles, having to double efforts on water conservation, water reuse, and diversification of water supplies. However, increasing water scarcity threatens to lead to higher water rates, increased incidences of wildfires and land subsidence, an impact on flora and fauna, and adverse impacts on agriculture and other businesses critical to a city's economic health.

WATER EXCESS

At the other end of the spectrum, cities can struggle with too much water. Suffering during heavy rainfall, many cities lack enough green space to buffer heavy rains, and coastal areas are hindered by sea-level rise and storm surge. A city like Rotterdam has learned to deal with these water excess challenges through the strategic Dutch Delta Plan.

On the other hand, the city of Jakarta with rapid urbanization and record soil subsidence, is facing daily water challenges. Without substantial short term countermeasures, the lives of millions of people will be impacted by semi-permanent flooding in the Northern part of the city.

AGING AND INADEQUATE INFRASTRUCTURE

Aging and inadequate water and wastewater infrastructure contributes to both scarcity and flooding, as well as inefficiency. The economic crisis and historically insufficient funding for water infrastructure has forced many utilities to delay improvements which have led to a deteriorated and unreliable system. The problems associated with these issues can significantly reduce a city's competitiveness.

Cities such as London, Berlin and New York suffer from the impacts of aging infrastructure. The American Society for Civil Engineers regularly issues a report card on the status of infrastructure in the United States. In recent years, this report card gave the country's water and wastewater infrastructure a "D" grade, meaning it is in poor condition due to the infrastructure being near or past its capacity and life expectancy. Significant capital investments will be required to fix, replace, and expand pipes, levees, waterways and other critical water infrastructure, as well as upgrade or expand treatment.

CLIMATE CHANGE

Changing weather patterns threaten to leave some areas in persistent drought while others experience cloud bursts, mega storms and rising sea levels that lead to flooding. In recent years, superstorms like Hurricane Katrina in New Orleans and Typhoon Haiyan in the Philippines produced unprecedented storm surges that devastated flood protection systems and the communities they were designed to protect. On the other hand, cities like Los Angeles and São Paulo recently faced unparalleled water shortages.

In response, Los Angeles imposed severe measures to stiffen the rules on water conservation and to curb excessive water use, up to and including shutting off supplies and even considering the use of the public weapon of "drought shaming". São Paulo was confronted with the worst drought in 80 years, which resulted in the city's two main reservoirs, the Cantareira reservoir and the Alto Tietê reservoir being almost empty. São Paulo was brought back from the brink of a water crisis when El Niño brought in heavy rainfall in February 2016 that restored reservoir levels

SECURITY AND BUSINESS CONTINUITY

The infrastructure associated with drinking water and wastewater services is critical to the functioning of both cities and nations; and thus can be a targeted by bad actors – whether cyber hackers or other malicious adversaries. Key resilient elements are protecting critical assets and making sure that a system can be quickly restored to service after disruptive events. Nations and cities across the globe vary broadly in how they address water and wastewater systems as a critical infrastructure that needs to be protected, and to what extent cities and utilities plan for failure and recovery. However, with the increased automation of every aspect of life - including of critical infrastructure, and with cybersecurity taking center stage as a global threat, the focus on infrastructure security and preparedness at the utility level is on the rise.



CITY PROFILE: WUHAN

Overall ranking: 40 Resiliency: 26 Efficiency: 31 Quality: 41

Wuhan, with more than 12 million residents and the most populous city in Central China, is working hard to deal with water stress, as well as with water balance and reserve water. Flooding from the main Yangtze and Han rivers has been strongly diminished by building high levees and by the constructing the Three Gorges Dam. But the location of the city in a large plain still makes the city vulnerable to flooding due to intense rainfall.

Extensive building activities have put a stress on the retention capacity of the city, as in the last decades many lakes and green areas have been urbanized thus the urban drainage system became overwhelmed. Presently the municipality is working hard on improvements. Wuhan was one of the main cities to be selected as a pilot for the so called “Sponge City” Program, which was established in response to the alarming statistic that the number of Chinese cities affected by flooding has more than doubled since 2008 due to rapid urbanization. Arcadis was recently selected by the city of Wuhan to be the lead consultant of the Sponge City Program.

The name Sponge City refers to the innovative solution to create more green public spaces to absorb stormwater, making the city more permeable and resilient to climate change. Ultimately, the city has a goal to manage 60 percent of the rainwater and serving as an example to other Chinese cities.



CITY PROFILE: LOS ANGELES

Overall ranking: 27 Resiliency: 48 Efficiency: 2 Quality: 21

Los Angeles comes in second in the efficiency Index, with only Copenhagen topping it. It joins Jeddah and Riyadh as top performers in wastewater reuse. However, various features of the city's natural environment create sustainability challenges. It has suffered incidents of all five major natural water-related disasters, as well as its fair share of floods. Chronically high water stress and distant water supplies (over 85% imported from over 100 miles away) strain its ability to provide a consistent supply against drought. The propensity for seismic scenarios could prevent the city from receiving enough water for prolonged periods of time.

LA is responding to their challenges in the short and long term, starting with the gubernatorial-mandated 25% water use reduction and earthquake preparedness initiatives as well as the adoption of the One Water LA plan which will set the bar for a more sustainable and resilient way to manage the City's future water needs through a collaborative approach yielding sustainable, long term water supplies for Los Angeles in addition to greater resiliency to drought conditions and climate change.

Los Angeles receives the top score for water reuse based on the large capacity of facilities in its vicinity. It has also been very successful in reducing non-revenue water, and boasts one of the most successful conservation programs.



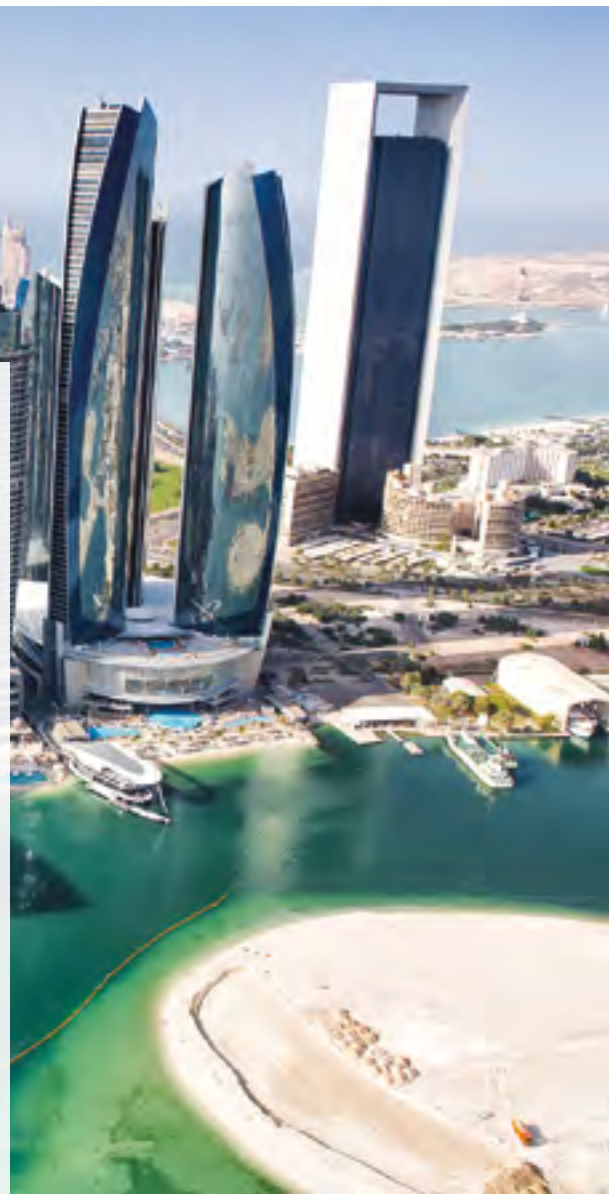
CITY PROFILE: ABU DHABI

Overall ranking: 38 Resiliency: 33 Efficiency: 39 Quality: 43

Abu Dhabi, ranking second among its regional peers, is in a geographically vulnerable water situation with high water stress. Like its neighbors, it obtains the majority of its water through desalination due to the lack of natural freshwater sources. This lack of naturally sustainable water resources is reflected in the reserve water, water balance and water stress indicators.

Abu Dhabi works towards sustainability through the use of treated sewerage effluent for landscaping. The rapid urbanization brought to the forefront the need for efficiency and to make progress against its natural risk Abu Dhabi is investing heavily in its capital program. In terms of non-revenue water, Abu Dhabi comes in second in region. ADSSC has a vision to achieve excellence in the provision of high quality, cost effective, safe and environmentally compliant sewerage systems in the Emirate of Abu Dhabi.

*Some data points for Abu Dhabi and Dubai are only available for the UAE on a country-level basis versus city specific data. Therefore, the wider country data is applied to Abu Dhabi in a broader interpretation, potentially having adverse effects on Abu Dhabi and Dubai's overall rankings, particularly in the water quality sub-Index's indicator of water-related disease.





CITY PROFILE: LONDON

Overall ranking: 21 Resiliency: 14 Efficiency: 34 Quality: 26

London's ranking for efficiency is relatively anomalous in terms of its overall ranking. Rates of water metering are very low by international standards. British utility companies are increasingly moving towards metered supply, but this remains unpopular with the public. London leakage rates are also fairly high as a result of underinvestment despite ongoing efforts to replace the city's aging Victorian sewers.

Despite ongoing improvements, pollution levels in the city's source water are still among the highest in the Index. The Thames River is negatively impacted by upstream pesticide use in farming as well as combined sewer overflow. Investment in projects such as the Lee Tunnel and Thames Tideway Tunnel will significantly improve water pollution in the city.

London is in a dynamic resiliency situation as rapid urbanization in the flood plains and an aging storm surge barrier system increasing the vulnerability to future flooding.



CITY PROFILE: MANILA

Overall ranking: 48 Resiliency: 50 Efficiency: 41 Quality: 50

Manila outperforms some of its Asian peers in efficiency as its metering, wastewater reuse and water charges are higher than its regional peers, but it has room for improvement on the resiliency and quality indices.

The greater metropolitan area is characterized by extensive informal settlements which developed without proper urban planning. Flooding after rainstorms occurs regularly and levels of drinking water and sanitation provision are low. The Philippine capital has a sanitation coverage rate of just 12%, one of the lowest in the Index.

The other large challenge that Manila faces is an adverse geographic location with one of the most challenging climates on earth, as The Philippines is the most-exposed large country in the world to tropical cyclones (typhoons). Manila is prone to frequent flooding and four different types of water-related natural disasters. Metro Manila is now with support of the World Bank planning for a flood protection program. The city's score on water balance is also very low, due to a sizeable precipitation deficit in certain months and a huge surplus during the rainy season.



4.2 HOW TO CREATE A SUSTAINABLE WATER FUTURE FOR CITIES

There is not one single winning strategy for each city's urban waterscapes. As the Index demonstrates, natural and manmade circumstances and challenges differ from city to city. In this section, we recommend approaches for dealing with urban water challenges based on our global experience, strategic viewpoint and water heritage. We believe these can be building blocks for developing winning water strategies and valuable food for thought for those responsible for their city's water planning and development.

SUSTAINABLE STRATEGIES AND BEST PRACTICES

This Index clearly shows that many of the world's cities still have steps to take to become sustainable or have the capacity to endure natural and manmade water challenges. Alternatively, they may not have policies and practices in place that allow them to efficiently manage their water resources to optimize water quality and quantities.

Even higher ranked cities are not ready for the challenges brought by changing circumstances, including climate change, extreme weather, and other disruptive events. It is important to understand that sustainability is not only a matter of water but, rather, it is also about the social, economic and governmental challenges that interconnect with each other. The pathway to ensuring a city is truly sustainable must take all these aspects into account.

Clearly, becoming more sustainable could easily be bogged down in the endless details and contingencies and bureaucracy. However, there are many things that can be done. Let us take a look at some strategies and best practices that can make our urban world fit for the future by making it a better and safer place to live, visit and conduct business.

THE ASSET LIFECYCLE



PLANNING

RESILIENCY AS A PATHWAY TOWARDS SUSTAINABILITY

Major cities worldwide have now placed resiliency planning on the agenda, an initial step to becoming more sustainable. To give urban resiliency top-level visibility, The Rockefeller Foundation pioneered a 100 Resilient Cities Initiative. It is expected that 100 'Chief Resiliency Officers' will advance policy, planning and funding. These plans and new inter-urban dialogues have, in some places, already put forward a new, broader definition of resiliency and demonstrated how these cities can prepare to recover from the uncertainties of the future.

This dialogue is having a profound effect on how cities look at water management, and beyond. In her book, *The Resilience Dividend*, Judith Rodin president of the Rockefeller Foundation, explores the new era of resiliency planning. She defines it as "the capacity of any entity – an individual, a community, an organization, or a natural system – to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience."

By this way of thinking, the scope of resiliency is not just about structures and protection but also is about preparing to

recover. Resiliency extends to the 'soft' infrastructure of society, including employment, income distribution, social cohesion and a range of factors not usually built into water management. It also includes the planning and design for alternative ways of funding. For example, it is expected that cities that have good economic and social resilience can also recover faster from a catastrophe or unplanned emergency such as a flood. A resilient city also has robust vital infrastructure and services, such as hospitals, electricity, telecommunications and transportation. When these recover quickly, it is for the good of the city, its citizens, businesses and environment.

URBAN ADAPTIVE PLANNING

The way we deal with natural disasters is usually reactive. For example, it used to be typical to design the best protection to safeguard a city after a devastating storm with the aim of preventing a similar future disaster. Time and experience has proven this approach to be only moderately successful. More recently, however, proactive planning and design processes are employing statistics and modelling to design for hypothetical scenarios, potentially saving lives and making cities safer *before* the disaster.

However, with the abundance of challenges our urban world is now facing, it is difficult – and maybe impossible – to exactly plan and design for the mid and long term future. It is precisely for this reason that modern planning practices have to be adaptive and risk-based, as well as flexible enough to account for unexpected circumstances or developments.

A good example of an adaptive planning practice is in San Francisco, where they have responded to their natural vulnerability risk through a comprehensive assessment of Mission Creek and Mission Bay, two of the lowest lying parts of the city. Formerly an industrial area with primarily port facilities and rail yards, the Mission Bay area is now being redeveloped for residential and commercial use. The first step is assessing the vulnerability of important infrastructure using sea level rise 'inundation maps' and working with different city departments to ascertain potential weak points and respond accordingly.

OPTIONEERING: MAKING INVESTMENT AN APPEALING CHOICE

Cities are often the economic strongholds of their region. However, funding for investments in water sustainability is often difficult to find. Especially because the benefits of such investments are not immediately obvious and are not always the most eye-catching or politically interesting. This is why city administrations tend to postpone these investments.

Most cities have many short term problems and plans that require investments, such as social housing, traffic congestion, more exposed critical infrastructure or leisure. An interesting way forward is combining some of these more immediate needs with longer-term water sustainability and climate change adaptation initiatives. This approach opens up additional opportunities to attract private funding, for instance green funds and climate bonds that generate return on investment. This is known as optioneering.

CREATING

MULTI-PURPOSE URBAN SOLUTIONS

Water infrastructure projects often require large investments and space, and in urban areas funding and space is limited. This makes innovative solutions that provide multiple functions increasingly attractive. This approach requires water engineers and planners to be well connected to the other needs and ambitions of the urban communities, and who can translate these in alternative, innovative designs.

For a city to be effective at managing resiliency and quality, it must also ably manage stormwater. Many cities are turning to green infrastructure projects to manage stormwater issues as an alternative to the traditional methods of piped drainage systems that were designed to capture and convey stormwater to waterbodies as quickly as possible, and may or may not have involved methods to address water quality. Green infrastructure is an approach to water management that more closely mimics the natural water environment, and incorporates both natural and engineered systems to effectively capture, attenuate, store and treat stormwater. At the same time green infrastructure can provide valuable green space and recreation for the residents of a city, reduce the urban heat island effect, and enhance biodiversity and ecological resilience.

The South Los Angeles Wetlands Park was designed to capture and treatment urban runoff, while also providing rare green space to an underserved community of Los Angeles. The project transformed a previously abandoned railyard, which was a brownfield site, into a park with trails, boardwalks, picnic areas and other features.

Harnessing the power of low-impact green infrastructure in cities not only swiftly reduces flood damage and restores areas to a more natural state should the worst happen, it also makes for a more balanced local eco-system. The likes of parkland, bio swales

and green roofs cannot completely replace traditional 'grey' storm drainage systems, which in many cases will remain the backbone of urban stormwater management. Rather, a balance can be struck between the two that produces an integrated, resilient system and allows cities to grow.

MANAGING AND OPERATION

OPTIMIZING URBAN WATER USE

Clean, safe and usable water is a limited and valuable resource. This is precisely why it is crucial to make sure water usage in cities is efficiently managed and wastage is kept to a minimum. Yet, in many cities water is not always treated appropriately and in fact may even be wasted. It is all too often taken for granted under the assumption that it is abundantly available, as well as inexpensive and simple to manage. However, efficiency is an area that many cities struggle with and one in which many developed cities underperform.

To accomplish this, cities must have a good enough knowledge of their assets and behavior of its system and the types and levels of usage (current and projected). They also must be aware of the vulnerabilities of the system, as well as the risks which could potentially cause distress in the system (on a short or long term basis) and that could hinder the cities operations, the well-being of its citizens, or even limit the city's competitive edge. Water sources along with treatment, delivery, and collection capacities and challenges; as well as compliance and quality requirements (both current and future) are all necessary aspects that cities must consider when developing their "as-is" and "future" optimization blueprints in their pathway towards sustainability.

URBAN ASSET PRESERVATION AND MANAGEMENT

Aging urban water infrastructure poses a serious challenge, weighing heavily on systems like an unpaid

debt. For several decades, and throughout the economic downturn, city authorities and utilities in most countries around the world held back on maintaining or upgrading water and wastewater infrastructure. Deferred maintenance and spending have resulted in a major funding gap. In the U.S. in particular, the sheer enormity of the funding gap is daunting, approximately \$600 million USD according to the U.S. Environmental Protection Agency. At the same time, population growth and urbanization require large investments in new water and wastewater infrastructure, not just in the U.S. but all around the world.

Large cities and public and private utilities assume that everything will be 'business as usual' forever. However, in the world of urban competition, the future will favor the creative, the innovative and the bold. The opportunity risk of foregoing improvements based on social, economic, and environmental consequences as well as the probability of failure can guide asset management decisions. The asset management standard, ISO 55000, is being used by utilities and cities that are looking to adapt and improve how they manage their assets.

Risk-based asset management approaches are more and more being used to prioritize capital and operating investments. This means allocating funds to address risks to those assets that have the highest potential of failure but also those where the consequences of failure have the biggest impact on the urban economy, environment and communities.

Until recently, such programs were performed by individual departments within an organization and have not been integrated into any organization-wide strategy, but with the ISO 55000 many large cities and utilities are revising their approach.

The Tarrant Regional Water District, outside of Dallas has the overall goal of achieving 100% reliability and optimized management of energy used to transmit raw water. As such, they have embarked on a project

that comprises the development of a formal asset management program that complies with ISO 55000 and the development of a real-time energy consumption optimization decision support tool.

MANAGE STORMWATER

When it rains, the water that runs off our roofs can be collected for future reuse with minimum hassle. Rainwater harvesting is increasingly practiced in larger urban facilities including sports arenas and recreational complexes. In many cities it is worthwhile to collect this water, instead of letting it drain into the subsoil or directly in collection systems. This approach is gaining popularity in many water scarce areas.

Singapore, for example, is currently committing to infrastructure that is designed to capture every drop of rain that falls. Los Angeles is capturing stormwater and using it to recharge drinking water aquifers, and the city of Melbourne is piloting a project to capture rainwater from roofs and store it in tanks to be used for toilet flushing and lawn watering.

SEPARATE GREYWATER

Residentially and commercially generated wastewater that has not been contaminated by sewage, known as greywater, may be used for cleaning or bathing. Greywater does not require the same level of treatment as most other water sources. It is for this reason that buildings should explore opportunities to separate their plumbing systems that carry this water. While potentially proving costly in the first instance, due to requiring additional infrastructure, it does create a more easily reusable water source over the longer term.

REDEFINING

DESALINATION

Taking saltwater from the ocean and turning it into usable freshwater is commonplace in many arid coastal locations. It is, in fact, the fastest growing alternative water supply source in the world and can be a valuable

weapon for cities looking to diversify their water supply and reduce water shortages. However, the costs of treating it, transporting it and disposing of the leftover brine can be high energy.

Generally, desalination has higher equipment costs and energy demand than wastewater reuse, plus disposing of the separated brine can pose an environmental challenge. The question for city leaders considering this option is whether the rewards of desalination warrant its implementation, and whether other alternatives such as conservation and water reuse can cost effectively reduce the quantity of desalinated water required. Cities should be actively looking at their water portfolio management to see if they have sufficiently diversified their options. Desalination can be a reliable source of drinking water that enables continuity and access for a city's inhabitants.

WATER REUSE

Effectively reusing and transporting water in a cost-effective and safe way can contribute considerably to water availability and can be crucial to meeting a city's long term demand. The water we drink often starts out as natural water that has been used before. For example, in cities downstream on a river are often drawing water for drinking water that includes effluent discharged from upstream wastewater treatment plants. This water source is then treated to bring it up to drinking water standards.

Increasingly cities are treating their own wastewater to levels such that it can be reused for agricultural, industrial, source water replenishment, and increasingly potable water uses. The level of treatment required is dependent on the end use and the end uses will vary depending on the particular conditions and needs of the city.

The Saudi Arabian cities such as Jeddah and Riyadh are investing in water reuse as a component of their strategy to manage water scarcity. Treated Sewage Effluent

(TSE) is increasingly being made available to industrial users and for irrigation to reduce the demand for potable water. The award winning Aquapolo project in São Paulo produces high quality industrial water from effluent from the ABC Sewage Treatment Plant for use by industrial users in a nearby petrochemical center, considered to be the biggest consumer of potable water in the region. This project not only will help reduce potable water consumption in a region where water is increasingly scarce, but it will also help reduce pollutant loading to the Tietê River.

Water reuse is very common in California. The West Basin Water Utility in greater Los Angeles has taken reuse a step further and introduced its 'designer water' program, providing up to five different types of water for various commercial, industrial and irrigation uses, as well as groundwater injection to create a barrier to prevent salt water intrusion into a valuable groundwater supply. The idea behind this is to treat only certain quantities to specific treatment levels that are needed to sustain demand at any given time. In essence, they are treating water to order.

4.3 CONCLUDING REMARKS – WHERE NEXT?

Water is paramount to a city's sustainability, but too often it is being wasted, polluted and taken for granted, while its potential to disrupt communities and businesses is not being taken seriously enough.

Yet people expect healthy access to it, safety from it and city leaders should view it as an opportunity and a resource for economic development. The Arcadis Sustainable Cities Water Index attempts to inspire cities to compare, collaborate and learn.

To succeed in an increasingly complex world, the world's cities need to focus on the opportunities that a healthy natural aquatic and municipal water system offers, and find answers to major challenges if they are to thrive and remain competitive over the coming decades.

The good news is there are inspirational efforts currently in place in many of our global cities to improve provision of water. At present, around ninety percent of the world's population has access to clean drinking water. This does represent a significant improvement and means that we have met the UN millennium development goal in 2010, five years ahead of schedule. Clearly, the appetite is there to make things better, we just need to prioritize greater investment and move faster from the strategizing and goal setting into actions that improve the quality of life for every urban resident on this planet.



5. APPENDIX

5.1 METHODOLOGY

AUTHORSHIP AND ACKNOWLEDGEMENTS

The research that has informed this report was produced by CEBR, an independent economics and business research consultancy established in 1992. The views expressed herein are those of the authors only and are based upon independent research by them.

In partnership and consultation with the Centre for Economics and Business Research (CEBR), Arcadis developed the Sustainable Cities Water Index with the ultimate goal of being able to rank the sustainability of cities with respect to their water profile and systems. The Index centers around three key sub-indices for water sustainability: resiliency, efficiency, and quality. In turn, these sub-indices are made up of a series of indicators, such as flood risk, green space and pollution.

The research examines a representative sample of 50 cities from 31 countries across all continents of the world. The cities included within this report were selected to provide an overview of the world's urban environment, providing not only wide-ranging geographical coverage, but also a variety of levels of economic development, expectations for future growth and an assortment of water sustainability challenges. These cities also parallel Arcadis' 2015 Sustainable Cities Index that explored the three demands of People, Planet and Profit and provided an indicative ranking of 50 of the world's leading cities.

The indicators are weighted according to their relative importance to water sustainability and quality of life. A metric is developed for each indicator and a robust, evidence-based score is subsequently derived to quantify each city's overall performance. The breakdown of the indices also reveals where cities are doing well and where there may be room for improvement.

Each sub-Index is built using a number of indicators. The data behind these indicators are processed so that higher scores represent more sustainable cities, and give the highest-ranked city in each indicator a score of 100%, while the lowest-ranked city receives 0%, so that each city's performance within each indicator is measured relative to each of the other 49 cities. By averaging the indicators, a score for every city in each of the three sub-indices is derived. The three sub-indices are then combined to deliver an overall score. Some indicators, such as sanitation, are deemed to have importance to multiple sub-indices. The output is a percentage score: theoretically a city could attain 100% if it came top in every category, but in reality no city does.

It is important to recognize that personal and scientific opinions on the interpretation of the relative importance of indicators will differ. We have ranked the indicators according to our interpretation of the impact on the quality of life in cities: their people, environmental challenges and their natural assets. We hope this Index serves as a catalyst for a conversation on how cities can further plan around their water sustainability. Hence the Sustainable City Water Index provides an interesting starting point of further analysis and debate. The table below provides the quality of life weighting rational.

INDICATOR	RANK	QUALITY OF LIFE RATIONALE
Drinking water	1	Essential to public health and survival
Sanitation	2	Essential to public health
Water-related disaster risk*	3	Essential to public safety, supply chain and business continuity
Flood risk*		
Water-related disease	4	Harmful to public health and economic progress
Water stress	5	Water shortages have a negative impact on the ecosystem, quality of life, future city development and business continuity
Water balance	6	A stable water balance is an indicator for a healthy urban water system
Water pollution	7	Polluted water is both a public health risk and limits recreational and commercial usability
Water reserves	8	Adequate safe yield and water reserves help a city through periods of water shortage, important for both public health and the economy
Service continuity	9	To safeguard drinking water supply and industrial water supply for business continuity
Leakage	10	Leakages cause loss of revenues to invest in the water system
Treated wastewater	11	To enhance the quality of urban ecosystems and quality of life in cities and enable reuse opportunities
Metered water	12	Serves the economical sustainability of the water system to accurately account for water use
Water charges	13	To finance water services and to stimulate economic use of the water and provide for cost recovery and finance system improvements
Green space	14	To store rain water, create space, add value to the urban ecosystem and fight urban heat stress
Threatened species	15	Biodiversity in eco systems improves the urban environment.
Reused wastewater	16	Puts less strain on supplies and builds in system efficiencies and return on investment

*Note: water-related disaster risk and flood risk are different indicators, but collectively ranked third.

In total, 17 unique input indicators enter the Water Index, two of which appear in two sub-indices:

- Six enter the Resiliency sub-index;
- Seven enter the Efficiency sub-index;
- Six contribute to the Quality sub-index.

The raw inputs are then transformed. Firstly, the desirable characteristics are given higher scores. This is necessary for the water pollution levels, for example, where higher scores indicate more polluted rivers. Second, all the raw inputs are scaled so that they vary from 0 to 1: the lowest-ranked city receives 0 and the highest 1, and the others are spaced between that with the same spacing as they had in the raw data. Where a data point is very far from the mean, the value is treated as an outlier and receives either 0 or 1, and the next highest/lowest data point is treated as the lowest score. This prevents situations where one or two cities receive an extreme score and there is little separation between the rest of the cities.

The United Nations Development Program uses a similar process in creating its Human Development Index¹.

The overall Index score is comprised of one third of the scores on each of the sub-indices.

¹See, for example, the UN Development Programme's Human Development Reports page: <http://hdr.undp.org/en/content/human-development-index-hdi>

RESILIENCY INDICATORS AND DESCRIPTIONS

INDICATOR NAME	DESCRIPTION	SOURCE
Water stress	Freshwater withdrawn as a percentage of the total available locally	World Resources Institute
Green space	Percentage of city area covered with green space	Economist Intelligence Unit, Siemens Green Cities Index
Water-related disaster risk	Number of different types of water-related natural disasters a city is exposed to, including floods, storms, droughts and mud flows.	EM-DAT International Disasters Database
Flood risk	Number of floods experienced between 1985–2011	World Resources Institute
Water balance	Monthly deficits and surpluses of rainfall,	Terrestrial Water Balance Data Archive (Willmott and Matsuura, University of Delaware)
Reserve water	Reservoir capacity within 100km of city, relative to total city water supply	GResD Global Reservoir and dam database of the GSWP

EFFICIENCY INDICATORS AND DESCRIPTIONS

INDICATOR NAME	DESCRIPTION	SOURCE
Leakage*	The proportion of water lost in transit. Includes unbilled consumption, apparent losses and physical leakage.	Smart Water Networks Forum, municipal water utilities, World Bank
Water charges	Average cost per cubic meter of water to consumers, relative to average income in city.	International Water Association, World Bank IB-NET, municipal water utilities
Metered water	Percentage of households whose water consumption is metered.	Municipal water utilities, World Bank
Reused wastewater	Wastewater reuse compared to total wastewater produced.	FAO-Aquastat, Water Reuse Association
Service continuity	Continuity of service, average hours per day over the whole network.	World Bank, municipal water utilities
Sanitation	Percentage of households with access to improved sanitation.	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation
Drinking water	Percentage of households with safe and secure drinking water.	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation

QUALITY INDICATORS AND DESCRIPTIONS

INDICATOR NAME	DESCRIPTION	SOURCE
Sanitation	Percentage of households with access to improved sanitation.	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation
Drinking water	Percentage of households using an improved drinking-water source.	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation
Treated wastewater	Percentage of wastewater treated.	FAO Aquastat
Water-related disease	Incidence of water/sanitation related disease per capita.	WHO/Global Health Observatory Data Repository
Threatened freshwater amphibian species	Percentage of freshwater amphibian species classified by the International Union for Conservation of Nature as threatened in an area.	World Resources Institute
Raw water pollution	Concentration of phosphorus and sediment yields from source	International Water Association
Drinking water	Percentage of households with safe and secure drinking water.	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation

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5.2 FURTHER READING



BUILT ASSET WEALTH INDEX 2015



GLOBAL INFRASTRUCTURE INVESTMENT INDEX 2016



SUSTAINABLE CITIES INDEX 2015



THE FUTURE OF ASSET MANAGEMENT



SUSTAINABILITY REPORT 2015

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