

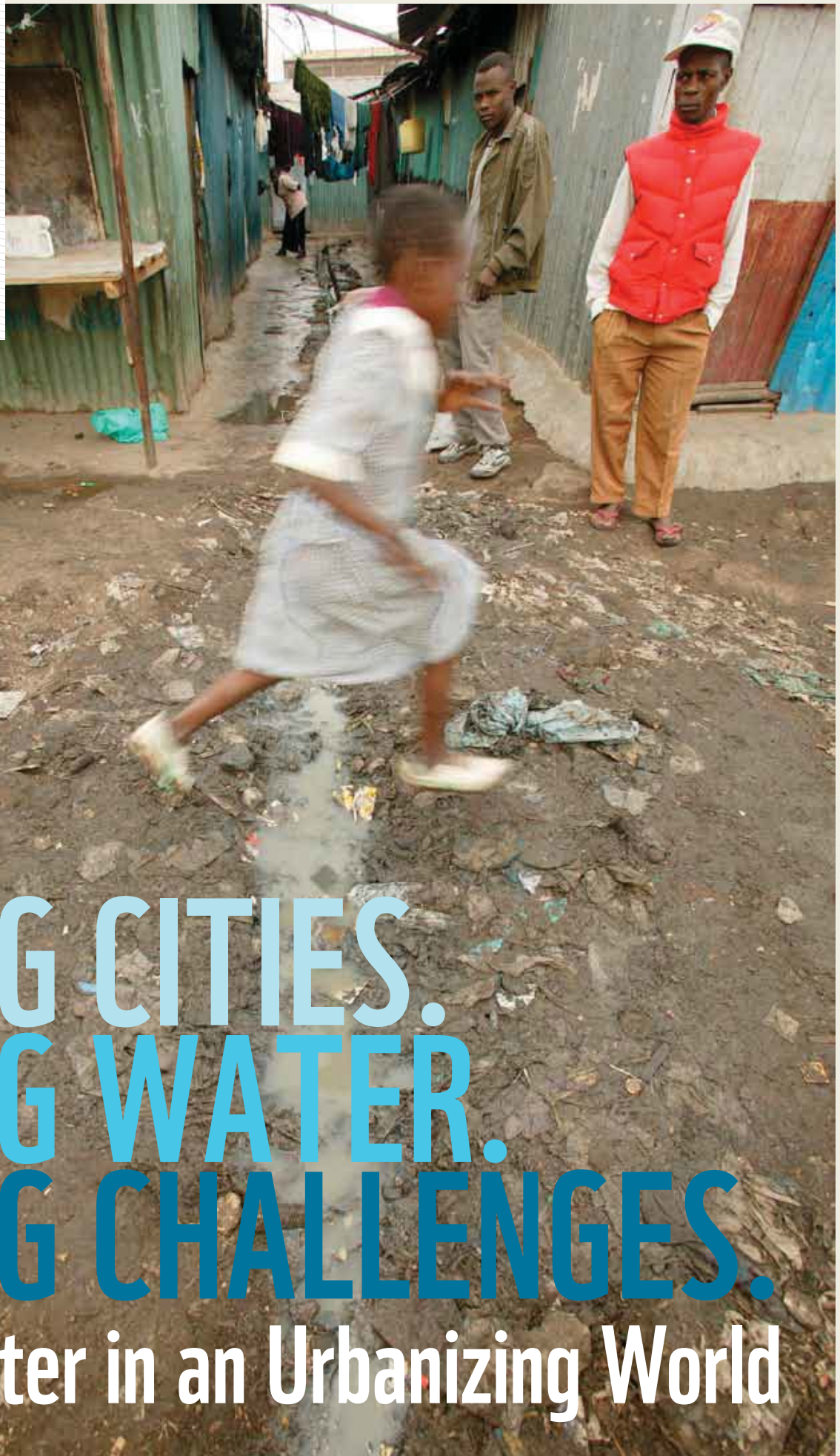


WWF

REPORT

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2011



BIG CITIES. BIG WATER. BIG CHALLENGES.

Water in an Urbanizing World

Imprint

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List of Acronyms

ADB	Asian Development Bank
AMSL	Above mean sea level
AWSB	Athi Water Service Board
AySA	Water & Sanitation Argentina (Aguas y Saneamientos Argentinos)
BDP	Basic Development Plan
CDGK	City District Government Karachi
CMR	Matanza-Riachuelo Basin (Cuenca Matanza - Riachuelo)
CONAGUA	National Water Commission (Comisión Nacional del Agua)
EKW	East Kolkata Wetlands
EKWMA	East Kolkata Wetlands Management Authority
ERAS	Water and Sanitation Regulatory Authority
FARN	Environment and Natural Resources Foundation (Fundación Ambiente y Recursos Naturales)
FGRA	Gonzalo Foundation Arronte River (La Fundación Gonzalo Río Arronte)
FVSA	Wildlife Foundation Argentina (Fundacion Vida Silvestre Argentina)
GDP	Gross domestic product
HIV	Human immunodeficiency virus
HMC	Howrah Municipal Corporation
IBT	Inter-Basin Transfer
IDB	Inter-American Development Bank
INDEC	Argentinian Statistics Bureau (Instituto Nacional de Estadística y Censos)
IPCC	Intergovernmental Panel On Climate Change
IRBM	Integrated River Basin Management
IUCN	International Union for the Conservation of Nature
KEIP	Kolkata Environmental Improvement Project
KMA	Kolkata Metropolitan Area
KMC	Kolkata Municipal Corporation
KW & SB	Karachi Water and Sewerage Board
KWP	Karachi Water Partnership
MDG	Millennium Development Goals
NCWCS	Nairobi City Water and Sewerage Company
PES	Payment for Environmental Services
PPP	Purchasing Power Parity
SACM	Water Systems of Mexico City (Sistema de Aguas de la Ciudad de México)
SEMARNAT	Environment and Natural Resources Minsitry (Secretaría de Medio Ambiente y Recursos Naturales)
UN HABITAT	United Nations Human Settlements Programme
UNEP	United Nation Environmental Programme
WHO	World Health Organization
WRMA	Water Resources Management Authority
WWAP	World Water Assessment Program (UN)
WWF	World Wide Fund for Nature
ZMVM	Metropolitan Mexico City (Zona Metropolitana Valle de Mexico)

EXECUTIVE SUMMARY



*Pollution over Mexico city.
Mexico*

The growth of the earth's urban population and areas continues as a major demographic trend; it is projected that 70 % of

the world's population will live in urban areas by 2050. Urban growth today is most rapid in developing countries, where cities gain an average of 5 million residents each month. Megacities and metacities – defined by UN Habitat as cities with more than 10 million inhabitants or 20 million inhabitants respectively – are gaining ground in Asia, Latin America and Africa. In most developing countries, urban growth is inextricably linked with slum expansion and poverty; in 2000, nearly one third of the world's urban dwellers lived in slums. As city infrastructure cannot keep pace with massive urban growth, many people are left without adequate access to drinking water and sanitation.

City inhabitants benefit from ecosystems that provide services, such as clean water, waste water treatment, agricultural products, clean air, and fossil fuels; however, net flows of ecosystem services into cities are increasing even more rapidly than urban populations, and so is the average distance of these flows. With a changing climate that can modify all elements of the water cycle, cities are particularly vulnerable to increased risks of flooding, insufficient provision of water in quantity and quality, sanitation, drainage, and effects on ecosystem services within and in the surrounding areas.

A city's impact on water, referred to as its "water footprint", traditionally analyses water quantity and quality, hydrological cycle of both groundwater and surface water, utilities, connectivity to the water network, and to a certain extent land-use/settlements. Expanding the concept of a city's "water footprint" visualizes the entire amount of water directly or indirectly embodied in any well-defined water consuming entity - its industrial and service sector development and changing energy needs. A city's water footprint would help further investigate the impacts a city has on water resources at a local, as well as, global level. Most mega-cities have an external footprint beyond their direct boundaries. When applied to cities, the water footprint methodology will help determine the diverse impacts of urban populations' consumption and therefore their indirect water footprint and where these effects are felt. By better understanding the wider water risks that urban areas and the regions supplying products, water, and services are facing, provides the cities' and regional governments and population the necessary information to take action in order to reduce, mitigate, or avoid those risks.

As seen in this report's case study chapter highlighting megacities with different social, environmental, and economic situations, the main threats to urban water are water scarcity, decreasing water quality and pollution, water overuse and associated salt-water intrusion in addition to infrastructural, institutional, and social problems.



*Brazil, Rio de Janeiro.
Rocinha Favela,
view across city.*

In Mexico City, over-exploitation of aquifers has contributed to the continued subsidence (five-40 cm per year), increasing the chance of catastrophic flooding. The dependence on distant water supplies has resulted in social and environmental conflicts with communities in the donor basin; in addition to the high energy costs (0.6 % of the country's total electrical energy generated) associated with pumping water over 1000 meters in elevation and 150 kilometers away.

Pollution levels in Buenos Aires' rivers are so high that they could be considered "open sewers". The Riachuelo, one of the most polluted water bodies in the world, has levels of Lead, Zinc and Chrome 50 times higher than the legal limit in Argentina; the river flows through a predominantly low-income area, with an above average frequency of children affected by intestinal diseases and the mortality caused by such infections.

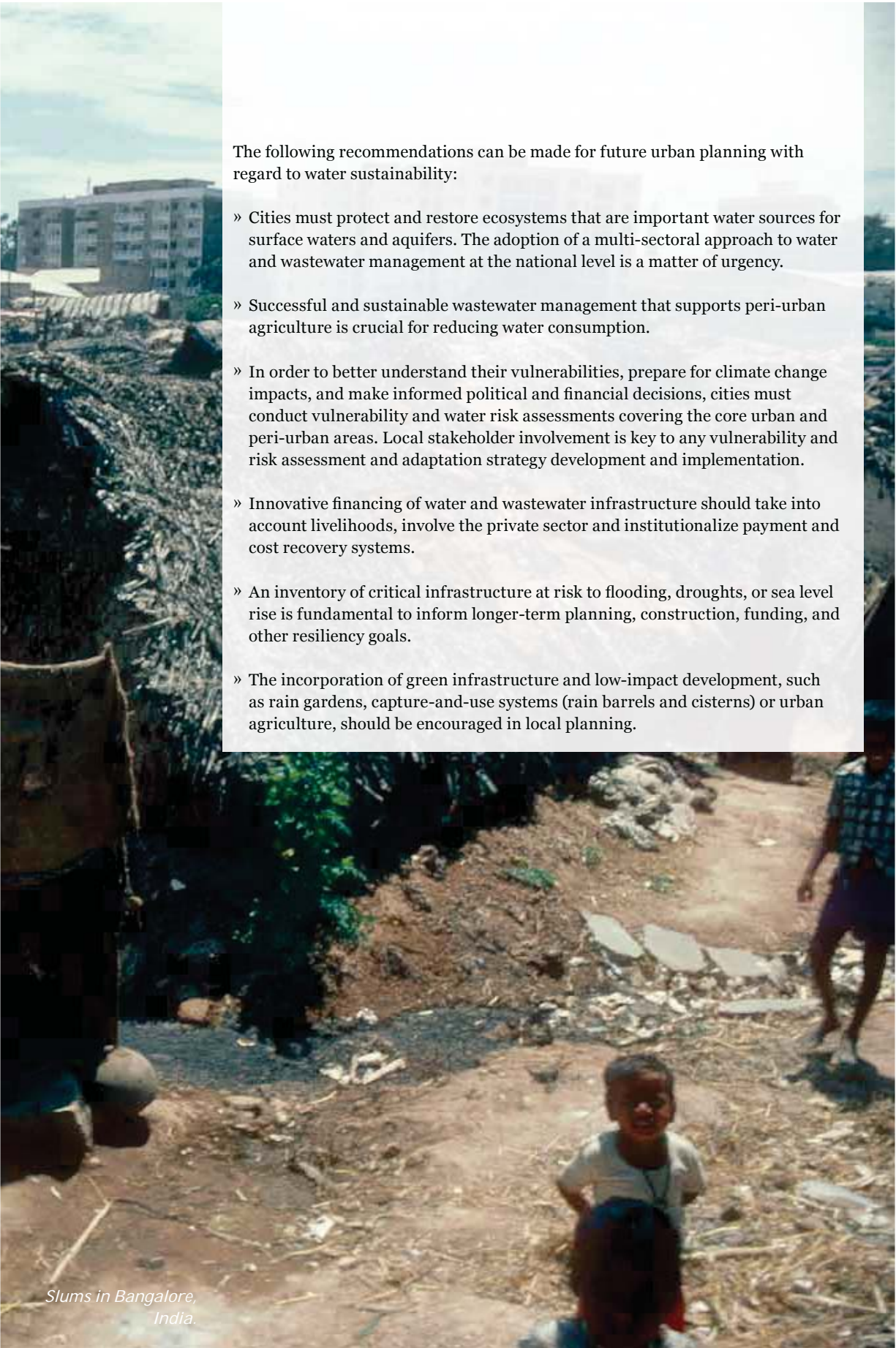
Nairobi lacks capacity to manage the city's increasing demand for water. Sixty percent of Nairobi's inhabitants live in informal settlements with inadequate access to quality water and are forced to buy their water at kiosks at a higher price. Additionally, the lack of access to sanitation results in untreated waste and wastewater not only endangering human health, but also deteriorating the river systems.

More than 50 % of Karachi's population lives in informal slum settlements and most of them face severe shortage of water as well as the lack of proper sewerage systems. Water stolen illegally from hydrants causes massive revenue losses of over US\$ 15 million annually. Eighty percent of untreated wastewater is discharged into the Arabian Sea and around 30,000 people, mostly children, die each year in the city due to consumption of contaminated water.

Kolkata is struggling with fecal contamination of municipal water and arsenic pollution of groundwater. The water management authority is unable to maintain its aging water supply and sewerage system; revenue recovery only stands at 15 % due to the lack of pricing domestic water, which also leads to water wastage.

Although freshwater is naturally abundant in the metropolitan Shanghai area, the city experiences high water stress due to the rising demand of 23 million inhabitants. Polluted rivers and saltwater intrusion in the Yangtze estuary, both of which are further aggravated by climate change, are the main threats to water security.

For cities to be sustainable, reliable access to safe drinking water and adequate sanitation are an important prerequisite. Sustainability goes beyond physical engineering and manipulation of water flows; Urban water management must integrate a larger proportion of solutions like raising awareness to reduce consumption, law enforcement and controls, reuse and recycling of storm-and wastewater, corporate water stewardship, economic and fiscal incentives and instruments, cost recovery, integrated river basin management, payment for environmental services, and climate change adaptation.



The following recommendations can be made for future urban planning with regard to water sustainability:

- » Cities must protect and restore ecosystems that are important water sources for surface waters and aquifers. The adoption of a multi-sectoral approach to water and wastewater management at the national level is a matter of urgency.
- » Successful and sustainable wastewater management that supports peri-urban agriculture is crucial for reducing water consumption.
- » In order to better understand their vulnerabilities, prepare for climate change impacts, and make informed political and financial decisions, cities must conduct vulnerability and water risk assessments covering the core urban and peri-urban areas. Local stakeholder involvement is key to any vulnerability and risk assessment and adaptation strategy development and implementation.
- » Innovative financing of water and wastewater infrastructure should take into account livelihoods, involve the private sector and institutionalize payment and cost recovery systems.
- » An inventory of critical infrastructure at risk to flooding, droughts, or sea level rise is fundamental to inform longer-term planning, construction, funding, and other resiliency goals.
- » The incorporation of green infrastructure and low-impact development, such as rain gardens, capture-and-use systems (rain barrels and cisterns) or urban agriculture, should be encouraged in local planning.

*Slums in Bangalore,
India.*

CHAPTER 1: INTRODUCTION

Water in the context of urbanization is gaining increasing attention; on UN World Water Day 2011, a number of reports dedicated to this topic were published and Stockholm World Water Week has set *Water in an Urbanising World as its theme for 2011*. As urbanization continues to increase globally, cities are becoming progressively important in every discourse, including those concerning water and Integrated River Basin Management (IRBM). The fairly recent phenomenon of megacities is of particular concern due to their sheer size, which is sometimes larger than the population of entire countries, and the corresponding demands on the environment.

This report analyses these influences and the resulting issues by looking at six such cities from around the globe. This report is not based on new scientific findings, but rather explores different approaches towards managing water. Traditionally, urban water issues focus on direct water use, sewerage, pollution, and infrastructure; however, it is important to investigate up and downstream impacts when considering urban water management and planning. A city's impact – particularly, the strain cities pose on their surrounding areas – gains a fully new perspective and must also be considered. By summarizing possible water management solutions and suggesting recommendations, we hope to leave the reader with a better understanding of *water in an urbanizing world*.

Lone child in a Mexico City slum. Mexico



AN URBANIZING WORLD

The relative and absolute growth of the earth's urban population and areas continues as a major demographic trend. During the 1950s and for the next 30 years, urban populations exploded around the world, and while this rate has slowed down, it is projected that 70 % of the world's population will live in urban areas by 2050 (UN HABITAT, 2008). Currently, half the world's population is urban, and with projected population growth being exclusively concentrated in urban areas over the next 30 years, developing regions will have more people living in urban than rural areas by 2030 (UN HABITAT, 2008). Urban growth today is most rapid in developing countries, where cities gain an average of 5 million residents each month (UNEP, 2011). Megacities and metacities – defined by UN Habitat as cities with more than 10 million inhabitants or 20 million inhabitants respectively – are gaining ground in Asia, Latin America and Africa and are spurred by economic development and increased populations (UN HABITAT 2006).

In most developing countries, urban growth is inextricably linked with slum expansion and poverty. Sixty-two percent of sub-Saharan Africa's urban population and 43 % of south-central Asia's urban population live in slums¹. In 2000, more than 900 million urban dwellers lived in slums, representing nearly a third of all urban dwellers worldwide². Though the proportion of the developing world's urban population living in slums declined in the past 10 years, the absolute numbers of slum dwellers has actually grown considerably, and will continue to rise in the near future (UN HABITAT, 2008).

City infrastructure has often not kept pace with the massive urban growth, leaving many people, above all those in informal settlements and slums, without adequate access to drinking water and sanitation, which represents one of the major challenges confronting cities today. Having to rely on private vendors for their daily water supply, the urban poor pay up to 50 times more for a liter of water than their richer neighbors (UNEP, 2011). A central component to the adopted international development goals and targets, including most notably the Millennium Development Goals (MDG), is to reduce the share of the population without adequate water and sanitation services (McGranahan et al., 2005). Diarrheal diseases alone are responsible for approximately 1.7 million deaths of children under the age of five every year – a death toll exceeding the combined under-5 mortality burden attributed to malaria and HIV (WHO, 2008). Investments in drinking water supply and sanitation show a close correspondence with improvement in human health and economic productivity (Vörösmarty et al., 2005).

Invariably, cities consume more ecosystem services than they produce, and create an additional strain on ecosystems through water pollution. As the demand for living space continually increases, concrete and asphalt cover areas that are actually needed for groundwater recharge (Tortajada, 2003). While only generating 0.2 % of global freshwater supply, urban ecosystems serve 4-5 billion people (Vörösmarty et al., 2005). City inhabitants benefit from ecosystems that provide services, such as clean water, agricultural products, clean air, and fossil fuels; however, net flows of ecosystem services into cities are increasing even more rapidly than urban populations, and so is the average distance of these flows. By importing goods, urban consumers draw on ecosystem services from other parts of the planet (McGranahan et al., 2005).



WATER FOOTPRINT OF CITIES

Water is a critical component for human survival, but with the continually increasing demand on this finite resource, we must find a sustainable balance. By calculating the water footprint, which measures the total volume of water used to produce goods and services that we consume and accounts for the volume of green (rain) and blue (withdrawn) water consumed in the production of agricultural goods from crops and livestock – the major uses of water – as well as the grey (polluted) water generated by agriculture and from household and industrial water use, we can incorporate a more holistic assessment of the demand placed on water resources by humans to calculate water availability (Li et al., 2010). Decision makers and resource managers can use these values to inform discussions on the sustainable and equitable allocation of water (Hoekstra et al., 2011). Irrespective of where the goods and services are consumed or produced, the water footprint can evaluate the pressures being placed on ecosystems.

So far, the water footprint methodology has found little to no application for cities.³ Such an analysis can however help to show how a city populations' high consumption of water and products and services in which water is embedded have an impact on the surrounding rural communities and ecosystems, and also at the global level. Going beyond a water footprint, no holistic assessment of a city and its surrounding regions supplying them with goods, services, and water has taken place yet.

CLIMATE CHANGE

The IPCC has documented that overall, the global climate is becoming warmer and wetter, and that precipitation extremes as well as the severity of extreme events themselves are expected to increase globally (IPCC, 1996; Matthews & Quesne, 2009). The implication of a changing climate is that all elements of the water cycle, including precipitation, evapotranspiration, soil moisture, groundwater recharge, and runoff may be modified. Additionally, it may change the timing and intensity of precipitation, snowmelt, and runoff (Vörösmarty et al., 2005).

Climate change impacts freshwater in three different but inter-related aspects: water quality, water quantity, and water timing, with a change in one often affecting the rest. Water quantity is most dramatically witnessed through floods and droughts (Matthews & Quesne, 2009).

As the world's population relies on freshwater – be it from reservoirs, lakes, rivers, or groundwater – dramatic impacts on economic activities, disease vectors, local livelihoods, and ecosystems qualities (i.e. fire regime, onset of spring) are expected as a consequence of climate change (Matthews & Quesne, 2009). Urban areas are particularly vulnerable to increased risks of flooding, insufficient provision of water, sanitation, and drainage, and effects on ecosystem services within and in the surrounding areas. Ninety-three percent of cities surveyed by the Carbon Disclosure Project identified themselves as at risk to climate change, with increased severity of storms and floods, rising sea level, temperature changes, drought, and more intense rain fall being cited most frequently as the effects experienced (CDP, 2011).

THREATS TO URBAN WATER

Will water resources still be adequate in an urbanizing world? How does urbanization change the demand and the use of water? What measures have to be implemented to meet the demand of growing cities?

At this critical point of urban growth and development, studying the underlying drivers, lessons learnt, and best practice of water issues in megacities around the world can help to provide sustainable approaches, flexible strategies, and feasible solutions to this pressing problem.

For the scope of this study, we chose six megacities in Latin America, Asia, and Africa with different geographical locations (coast, river estuary, inland, high elevation), climates, economic development levels, and main threats to water provision. Some cities rely on river water abstraction, whereas others mainly extract groundwater. There are different levels of institutional management and water source protection in place. Most megacities, however experience these direct threats:

Definition: An area is experiencing water stress when annual water supplies drop below 1,700 m³ per person. When annual water supplies drop below 1,000 m³ per person, the population faces water scarcity, and below 500 m³ „absolute scarcity“ (UN Water, 2006).

Water scarcity/stress. Water scarcity is both a natural and a human-made phenomenon. Due to specific geographic or hydrologic conditions, a city's water supply may not meet the demand of a growing population. Water is either over-abstracted to the point that it cannot recharge sufficiently or distributors shorten, interrupt, or distribute supply unequally between commercial, industrial, and domestic users, which in the worst case, leads to social conflicts. Water scarcity can be a consequence of overuse, abstraction, or infrastructure development in upstream areas. Dams, inter-basin water transfers (IBT), and extensive irrigation for “thirsty crops” are all factors that can alter the natural flow regimes and discharges of rivers and thus reduce downstream water availability (Pittock et al., 2009). The degradation of water quality, inter-sectoral competition, and inter-regional and international conflicts may also result in water scarcity (UN-Water, 2007).

Problem faced by: all case study mega-cities

Decreasing water quality and pollution of rivers and groundwater resources is one of the main threats to water sustainability in urban developed areas. Drivers can be located in the catchment area or in the direct surrounding. Main sources of point and non-point pollution (pathogens, organic and inorganic pollutants) are agricultural runoff, untreated industrial and domestic wastewater, as well as storm water and urban runoff. Although technical solutions have improved significantly, wastewater treatment and sanitation is still a global problem in megacities.

Decreasing water quality is also caused by degradation and land use changes in the catchment area. It has been shown that forest protection within the watershed leads to improved water quality while deforestation results in poor water quality (Dudley & Stolton, 2003). When natural water purification fails due to pollution and ecosystem degradation, high costs for water treatment are incurred. In many urban areas, traditional water tariff systems do not charge for these increasing costs, thus other payment schemes must be developed.

Problem faced by: all case study mega-cities

Water overuse. When too much groundwater is removed from aquifers, pore pressure drops and aquifer compression results, which may lead to land subsidence – a drop, or sinking of the ground surface. In coastal areas, subsequent **salt-water intrusion** further compounds the problem of securing a city’s water supply. When river surface water is unsustainably abstracted, it may not directly affect the immediate area; however, ecosystem degradation, pollution, and water scarcity is often experienced downstream.

Problem faced by: Mexico City, Kolkata

Urban vulnerability to climate change is to a high degree water related. Due to climate change, cities face both periods of too much and too little water as well as the intrusion of salt water in coastal areas. Extreme weather calamities, like floods and droughts, which are occurring more frequently and intensively, lead to shortcomings or a complete breakdown in the provision of quality freshwater, sanitation, and handling of storm water. In many cases, poor urban planning has caused a degradation of ecosystems on which the cities depend, thereby reducing the area’s resilience to climate change (IPCC, 2008).

Problem faced by: Shanghai, Karachi, Buenos Aires, Mexico City

Additional issues that compound the above mentioned threats are physical, institutional, and social. Cities with outdated infrastructure (i. e. old and leaking pipes and treatment facilities), inadequate legal framework, low institutional and financial capacity and weak enforcement of water regulations are particularly affected by the above mentioned threats. Many urban areas spread across numerous geographical boundaries with no central agency responsible for resource management. In informal settlements throughout metropolitan areas, where lack of access to clean water and sanitation greatly affects the lives of the poor, water scarcity mainly depends on how institutions function and what management measures are undertaken to guarantee fair and safe access to water and an equitable distribution of resources (UN-Water, 2007).

Low water season at the city of Changsha, Hunan Province, China. The year before the picture was taken during a flood the water was as high as the road.



CHAPTER 2: THE WATER FOOTPRINT OF CITIES

Traditionally, when investigating a city's impact on water, or what in some cases would be referred to as its "water footprint", the analysis mainly refers to a city's

direct impacts on water quantity, water quality and in general the hydrological cycle of both groundwater and surface water, focusing mainly on the source areas for the water supply of a city and the waste water it produces. In addition, the majority of reports related to water and cities explicitly deal with their water utilities, how the population is connected to the water network, how many per cent of the city are connected to a waste water treatment system and in many cases also water pricing is a key issue addressed (ADB, 2004; Mafuta et al., 2011). Further legal/illegal and planned/unplanned expansion of cities into wetlands or flood prone areas, including potential aquifer recovery zones are mentioned, yet less frequently.

If this concept of a city's "water footprint" is further expanded, it includes any water infrastructure supplying a city with water or draining and cleaning the waste water, typically reservoirs and dams, inter-basin transfer systems, and ground and surface water systems, as well as drainage canals or wastewater pipe systems and water sanitation utilities. Though in researching detailed information on those, one will find decreasingly less information when one moves from developed via emerging economies towards least developed countries. This is very likely not only a factor of governance and transparency of the city administration and governance system, but also reflects the public scrutiny by civil society which in developed countries pushes the utilities towards increased transparency and disclosure of information. For instance, following pressure from citizens and a popular referendum, the Berlin's senate was forced to make public the contracts that were signed for a highly controversial partial privatization of Berlin's water utilities⁴.

Other direct impacts like thermal pollution stemming from the use of water for the cooling for energy utilities can be also considered a direct impact, but these are seldom reported on.



Center pivot irrigation of wheat crop, Mazabuka, Zambia, Southern Africa

The next level of a “water footprint” is when one starts considering indirect impacts through a city’s consumption - their industrial and service sector development and changing energy needs. There may be some confusion surrounding the term “water footprint” the way WWF uses and propagates this term as defined by the Water Footprint Network⁵ who have taken up the work on further developing the methodology around calculating a water footprint. This concept grew out of the idea of virtual water and was first envisaged and developed by scientists at Twente University. The water footprint visualizes the entire amount of water embodied in any well-defined water consuming entity (a product, a company, a nation, a city). For instance, for a piece of beef, the “water footprint” would entail the water used to grow feed for the cow, the water the cow itself consumed, the water used to clean the cow and the stables, etc. Further, the water footprint distinguishes between green, blue, and grey water. Green water effectively refers to rainwater and blue water to water abstracted from surface water. These two present direct water inputs. Grey water accounts for water pollution, and as the water footprint always gives a quantitative figure, it does so by taking the amount of water that would be required to dilute the polluted water down to the legal standards into the total water footprint equation. The grey water calculation is the most complex of the three and is therefore, not as broadly applied and frequently left out of water footprint calculations. However, as the methodology around the water footprint is currently evolving and under review by the Water Footprint Network and its partners, such as WWF, the applicability of the grey water footprint is bound to improve over time.

Over the last few years, largely due to WWF's initiative, water footprints have been calculated for individual nations (for instance the UK, Germany, and Switzerland, with a North America water footprint report to follow over the course of 2011). The approach taken distinguishes between internal and external water footprints, the internal describing water used within the respective country to produce goods consumed within this country and the external water footprint describing water used to produce goods outside of, yet consumed inside of the country in question (Sonnenberg et al., 2009).

Similarly to the national water footprints, a city's water footprint would help further investigate the impacts a city has on water resources at a local, as well as, global level. In fact, due to their sheer population size, some of the mega-city's metropolitan areas could be ranked at the same levels like countries as Sri Lanka, Australia, Romania, or Madagascar. As such, they have an external footprint beyond their direct boundary areas, even if some of it stays within the frontiers of the same country. When looking at the consumption of cities and their inhabitants, it is evident that the raw materials for near to all products will not be derived from within the city boundaries.

Agricultural produce, for instance, will to a large extent come from surrounding rural areas or from much further afield from not only rainfed but in many cases from irrigated agriculture. Unfortunately, urban agriculture is a niche phenomenon at a global level, albeit with regional variation in its extent and a growing prevalence in previously agriculturally unproductive cities in income rich countries, which have a lot of catching up to do, compared to Cuba for instance where urban agriculture was implemented on a large scale due to international trade embargoes forced upon the island (Cruz and Medina, 2003). Urban agriculture is an efficient way to reduce a city's external water footprint as well as utilizing runoff water, which would otherwise be drained into a city's sewerage system.

The exponentially rising energy demand of constantly expanding mega-cities also has strong implications for a city's water footprint. This goes for all kinds of energy generation. The growing of crops for biofuels for instance requires lots of water, holds a potential for pollution through fertilizers and pesticides, and land use changes may have adverse effects on local hydrology. Hydropower is obviously highly reliant on water and can again have strong implications for other water users or systems reliant on the river's flow. Coal power stations may require water for cooling, but water will also be used and potentially polluted during coal extraction and processing (Greenpeace, 2010).

Certainly, more relevant for some cities' water footprint than for others is the tourism development in peri-urban areas, which have their very own water needs and implications. This is also the case for industrial development zones and services located outside of city boundaries but catering for the needs within the city.

These examples are not exhaustive, but all clearly show that presumably the largest portion of a city's water footprint and impact is located outside of city boundaries of which in turn a fair share will fall into the surrounding rural areas. Therefore a more far-reaching approach to water planning and management, as well as, urban development should be taken by cities. The impacts of a city's water footprint on surrounding rural areas need to be assessed with associated risks identified and addressed. Far more interaction is necessary between the city administration and metropolitan water authorities with the surrounding regions and the entire watershed, or affected watersheds and authorities, communities, and water users.

The direct and indirect impacts, as well as competition a city's consumption might have on or with rural communities will vary in severity; therefore different responses will be required, which may mean new negotiations around water use and the application of innovative, fair, and transparent allocation mechanisms.

At this point in time, there has been very little research on cities' water footprints and the first analyses are yet to be conducted and the corresponding reports to be published. Given the higher density and usually larger consumption capacity of urban populations in comparison with rural ones, urban water footprints can be expected to be higher than rural ones and in particular, a city's footprint in its rural surroundings is likely to be higher than the footprint of the communities within that area. The image of a city draining water from its rural surrounding is therefore not farfetched. On the other hand, it must not be disregarded that cities present markets that rural producers' livelihoods rely on, this is especially true in less globalized consumption societies (Leach & Mearns, 1996).

When applied to cities, the water footprint methodology will help understand the diverse impacts urban populations' consumption and therefore their indirect water footprint have and where these effects are felt.

When considering the direct water footprint (the direct water use within a city, water treatment, etc), the entire range of possible impacts, as well as the associated current and future water risks need to be determined and decision-making must be based on these. This means integrating the issues as discussed above on groundwater, inter-basin transfer etc. into the assessments for urban planning and development.

Farmer opening up the irrigation channels for a potatoe plantation, Antalya, Turkey.





CHAPTER 3: CASE STUDIES – GLOBAL MEGACITIES & WATER

*Poisonous waste pouring
into canal. Plastic waste
accumulates in this foul
water. Jakarta, Java,
Indonesia*

MEXICO CITY, MEXICO

MEXICO CITY, MEXICO

GENERAL INFORMATION

Inhabitants	City (Distrito Federal): 8,851,080 ⁶ Total metropolitan area: 21,163,000 ⁷
Population density	5,912 person/ km ² - Mexico City 2009 668 person/ km ² - Mexico state 2009 (CONAGUA, 2011)
Population growth	15% ⁸
GDP (estimated in 2008, \$bn at PPP)	US\$ 390 billion (rank 8) (Hawksworth et al., 2008)
Contribution to national GDP	33% (IDB, 2008; Tortajada, 2006)
Area	7,854 km ² (CONAPO, 2005)
Climate	Temperate semi-humid, Arid & Semi-arid; Temperate humid (SMA, 2005)
Altitude	2,240 m.a.s.l. (SMA, 2005)
Mean temperature	16°C (SMA, 2005)
Mean annual rainfall	Arid – 50 mm; Temperate humid – 100 mm (SMA, 2005)

WATER STATISTICS

Domestic water use (liter per capita)	364 l Mexico City & 230 l Mexico state = 297 l on average in metropolitan area (Tortajada, 2003)
% households with water access	98% (Mexico City) (CCA, 2011)
% water loss due to leakage in pipe systems	> 40% (Tortajada, 2003)
Water price for domestic households	Mexico City = CONAGUA tariffs for 20m ³ (US\$/month) ⁹ : Popular \$3.50, Low \$5.10, Medium \$14.90, High \$17.00 (CCA, 2011)
% households with sewerage services	Mexico City = 94% (CCA, 2011)
% wastewater treated	Mexico City = 7.9% (CCA, 2011)
Main water sources	Groundwater Inter-Basin water Transfer from the Cutzamala & Lerma Rivers
Main water problems	Pollution Groundwater over-extraction Insufficient and leaking infrastructure Subsidence → flood risk

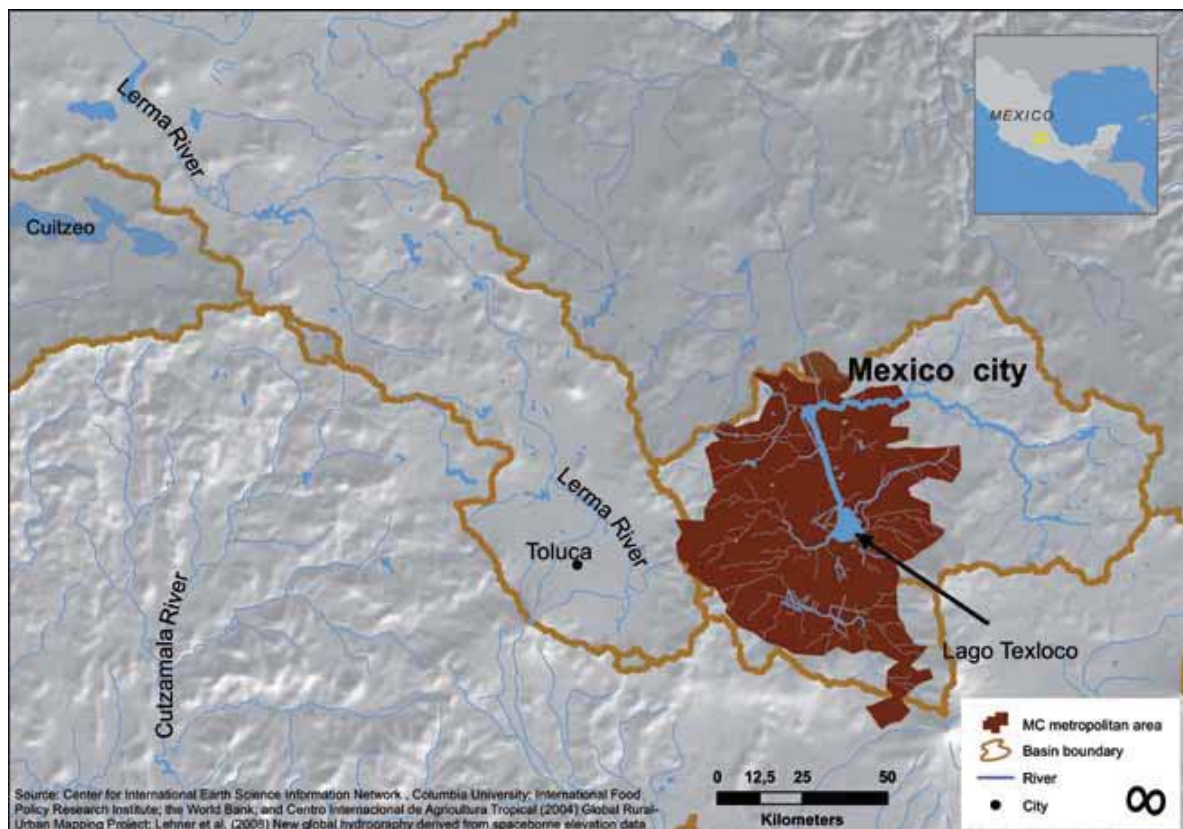
Mexico City's population exploded over the last century, growing from 1.75 million people in 1940 to currently over 21 million in the metropolitan area, making it the fifth largest metropolitan area in the world (City Mayor Statistics, 2011). In the 1950s, the City government forbade any further construction in the City, thus shifting growth outwards to the state of Mexico (Tortajada, 2006). From 1970 – 2000, the majority of the population growth continued in the State of Mexico with 320 % growth vs 35 % growth in Mexico City (Rojas et al., 2008). Over the last decade, metropolitan Mexico City's population growth has slowed down to 15 %.

Metropolitan Mexico City (Zona Metropolitana Valle de Mexico, or ZMVM) is comprised of 16 boroughs encompassing Mexico City, 59 municipalities in the State of Mexico, and one municipality in Hidalgo (CONAPO, 2005). The metropolitan area accounts for the country's highest concentration of economic activity – Mexico City and the state of Mexico produce 33 % of Mexico's GDP (Rojas et al., 2008).

CATCHMENT AREA

The metropolitan area of Mexico City lies in the Valley of Mexico basin, its water supply mainly stems from the northern aquifers of Mexico Basin, an extensive high mountain valley that is naturally closed, meaning there is no outflow to other water bodies. Nearly half of Mexico City's water stems from groundwater (Sosa-Rodriguez, 2010b); however, 2007's extraction volume of 59.5 m³/s was almost three times of the basin's natural recharge rate (Burns, 2009).

The metropolitan area's second most important water supply depends on inter-basin transfers from the Balsas (Cutzamala River) and Lerma (Lerma River) basins that provide 43 % of the total supply (Sosa-Rodriguez, 2010b). The Lerma System was built in 1942 and traverses 62 kilometers and is distributed to the City by gravity, while the Cutzamala System was developed in 1976 and is transferred from 60-154 km away, pumped over 1000 meters (Tortajada, 2006). The Cutzamala transfer system is actually one of the largest in the world due to the quantity (approximately 485 million m³ annually) and altitude (1,100 meter) that the water traverses to reach Mexico City (CONAGUA, 2011).





DRINKING WATER

Mexico City generally has better access to water and service as it has more economic and political power than neighboring Mexico and Hidalgo states. Though Mexico state represents 45 % of the metropolitan area, it only received 35 % of water from external sources in 1990 (Tortajada, 2006).

Of metropolitan Mexico City's 2.5 million water connections in 2000, 67% were domestic, but it is estimated that this only accounted for 64% of actual connections – the rest being illegal (Tortajada, 2006). Those that do not have access to water from pipes, pay private vendors from 6 to 25 % of their daily salaries (Tortajada, 2006). General distrust of tap water quality has led to much of the population purchasing drinking water; Mexico was ranked the third largest consumer of bottled water in 2009.¹⁰

WASTEWATER TREATMENT

Mexico City has 24 wastewater-treatment plants and the state of Mexico belonging to the metropolitan area has 41 plants (Tortajada, 2003, 2006). Ninety-four percent of the population in the Mexico City has sewage service, but only 7.9 % of the wastewater was treated in Mexico City in 2010 (information is not available for Mexico or Hidalgo State) (CCA 2011).

The City's Great Canal sewage system was originally built to function by gravity; however as the City continued to sink, it became increasingly necessary to pump waste- and storm-water. An additional system, the Deep Sewage line, was built in the 1960s to alleviate transport. The metropolitan area currently generates 40 m³/s of wastewater; however capacity is only built to handle 10 m³/s (Burns, 2009).

WATER GOVERNANCE & MANAGEMENT

Mexico's water is managed by the National Water Commission (CONAGUA), whose tasks are the 1) administration of national waters, 2) management and control of the hydrologic system; and 3) promotion of social development.¹¹ CONAGUA is an administrative, normative, technical, consultative, and decentralized agency of the Ministry of the Environment and Natural Resources (SEMARNAT) and is divided into thirteen regional administrations based on watershed/basin boundaries.¹² Since 1997, the Mexico Valley Watershed Regional Administration manages the metropolitan area of Mexico City's water supply. Though this watershed encompasses 16,438 km² and 116 municipalities in total, 92 % of its users are in the ZMVM.¹³

Currently, legal instruments are lacking to protect areas of recharge, and a series of adaptations to the National Water Law, General Law of Ecological Equilibrium, and General Law of Human Rights would be necessary (Burns, 2009).

MAIN WATER ISSUES

Mexico City has a long history of manipulating its water, stemming all the way back to 1324 when the Aztecs founded Tenochtitlan on a small island in the Lake of Mexico. Suffering from frequent droughts and floods, the Aztecs built a system of drains, dams, dykes, aqueducts, and constructed chinampas (an accumulation of aquatic plants and mud surrounded by swamps) to regulate water flows and quality, protect against flooding and droughts, and create more land for housing (Sosa-Rodriguez, 2010). During the Spanish colonization, the hydrology of the Basin was even further altered through the construction of infrastructure to drain the lakes and rivers from the Basin, which resulted in increased risks associated with devastating floods, low water quality, outbreaks of waterborne diseases, and the sinking of the city (Sosa-Rodriguez, 2010).

Over-extraction. As Mexico City's population exploded during the past century, existing infrastructure to supply water became insufficient to meet demand, which resulted in intensified groundwater extraction and water transported over greater distances (Sosa-Rodriguez, 2010). Currently, 4 of the 14 aquifers in the Valley of Mexico Basin are overexploited (CONAGUA, 2011). The per capita rechargeable water available for the Valley of México in 2010 is calculated at 163m³, whereas in 2030, it is predicted that rechargeable water per capita will be 148m³ (CONAGUA, 2011). Though the City has land set aside for conservation where groundwater sources could recharge, the frenzied population growth has led to many legal and illegal settlements, with 20% of illegal settlers living in riverbeds (Sosa-Rodriguez, 2010; Tortajada, 2006). Especially in the southern area of México City, where the soil is ideal for water recharge, the City has become heavily urbanized and covered in asphalt. The over-exploitation of the aquifers has contributed to the continued **subsidence** of Mexico City, which sits below the current level of Lake Texcoco and increases the chance of catastrophic flooding (Sosa-Rodriguez, 2010). In the mid 20th century, Mexico City's ground subsided a reported 40 cm/year in some areas due to the increasing extraction of groundwater; current rates lie between five and 40 cm/year (Jordan et al., 2010).

Inter-Basin Transfers. Despite water being supplied from further off Lerma and Cutzamala Rivers, thereby alleviating aquifer exploitation slightly in the Valley of Mexico, the dependence on distant water supplies has resulted in social conflicts with communities in the donor basin that did not receive compensation for the exploitation of their resource in addition to overexploiting their water sources (Sosa-Rodriguez, 2010). In the Lerma Basin, soil fertility has decreased and agriculture is mainly rain-fed in contrast to irrigation previously (Tortajada, 2006). In 2008, the cost for operating the Cutzamala System required the equivalent of 0.6% of the country's total electrical energy generated that year and 6.4% of CONAGUA's annual budget (CONAGUA, 2011). Though there were plans to extend the Cutzamala System at an estimated initial investment of \$502 million, the projected increases could be equally achieved through addressing the leakages in the distribution system (Tortajada, 2006).

The main sewage canal for the whole of Mexico City polluted with plastic and other rubbish. Mexico



Pollution. The City's wastewater is disposed of to surrounding rivers for removal to the sea, but this water polluted with untreated wastewater is also used to irrigate vegetables and cereals as farmers have found the high concentration of fecal bacteria to be an extremely effective fertilizer that increases their crop yield (Sosa-Rodriguez, 2010). Though there is a national norm regulating pollution limits in untreated wastewater, CONAGUA reported that the Valley of Mexico Basin had 50 % heavily contaminated, 25 % contaminated, 20.8 % acceptable, and only 4.2 % excellent water quality based on Biochemical Oxygen Demand levels sampled at selected sites (CONAGUA, 2011). The corresponding **health and environmental costs are increasing.**

MANAGEMENT MEASURES IMPLEMENTED/ SOLUTIONS EXPLORED

Institutional reform/privatization. Acknowledging that water could no longer be considered a public good (and, as a result, subsidized heavily by the State), but as an economic good – Mexico City launched an initiative to develop a pricing system based primarily on fixed tariffs through private sector participation in different stages of production, distribution and sale of water (Tortajada, 2006). The immediate measures included updating the legal and institutional frameworks and charges for discharging effluents into the sewerage system (a previous charge was only one-off payment to the National Water Commission). Longer-term measures were water charges based on metering and rehabilitating the distribution network to reduce leakages by 10–15 %. Until then, several institutions were involved in water management, creating over-lap of functions and unclarity; in 2003, the Water Systems of Mexico City (Sistema de Aguas de la Ciudad de México (SACM)) was formed.

The private sector became responsible for distribution, metering, billing, customer support, and maintenance of the secondary networks, and was given service contracts for specific activities over a limited period of time (Tortajada, 2006). Property rights to the infrastructure and control over the introduction of a new pricing system remained under the City government's control. An initial investment of \$152 million in 1992, and close to \$3 billion in 1994 was required to replace a system of fixed charges with one based on actual consumptions. The private sector had to offer the City government financing for the activities during the first stage and were responsible for detecting leaks (Tortajada, 2006). Initial response from officials, businessmen, academics, and the broader society was generally positive to the change (Tortajada, 2006).

Integrated River Basin Management. Created through the National Water Law, the Board of the Basin coordinates between the three levels of government, users, and societal organizations. Auxiliary institutions are the Basin Commission operating at the sub-basin level, the Basin Committee operating at the micro-basin scale, and the Groundwater Technical Committee operating at the aquifer level.

Flooding. With the objective of avoiding floods, diminishing the risk of drainage failures, and transporting wastewater to a treatment facility, CONAGUA began building the Túnel Emisor Oriente (TEO) in 2008 with a foreseen completion date of 2012. It will be 62 km long, 7 meters in diameter, and have a capacity of draining 150 m³/s wastewater.

Recharging groundwater. Water infiltration programs to recharge groundwater and **rainwater harvesting** recently started; however a slow start and minimal actions reflect the weak awareness and lack of environmental culture that still exists (Jordan et al., 2010). Mexico City began artificially recharging its aquifer with treated wastewater and rainwater in 1992 to combat subsidence. This practice is limited however as rainwater and wastewater are extracted in one shared pipe, and the associated cost of treating this larger volume of water is too high (Sosa-Rodriguez, 2010). Treated rainwater and wastewater is also used to irrigate green areas, fill lakes and canals, and cool industrial processes (Sosa-Rodriguez, 2010).

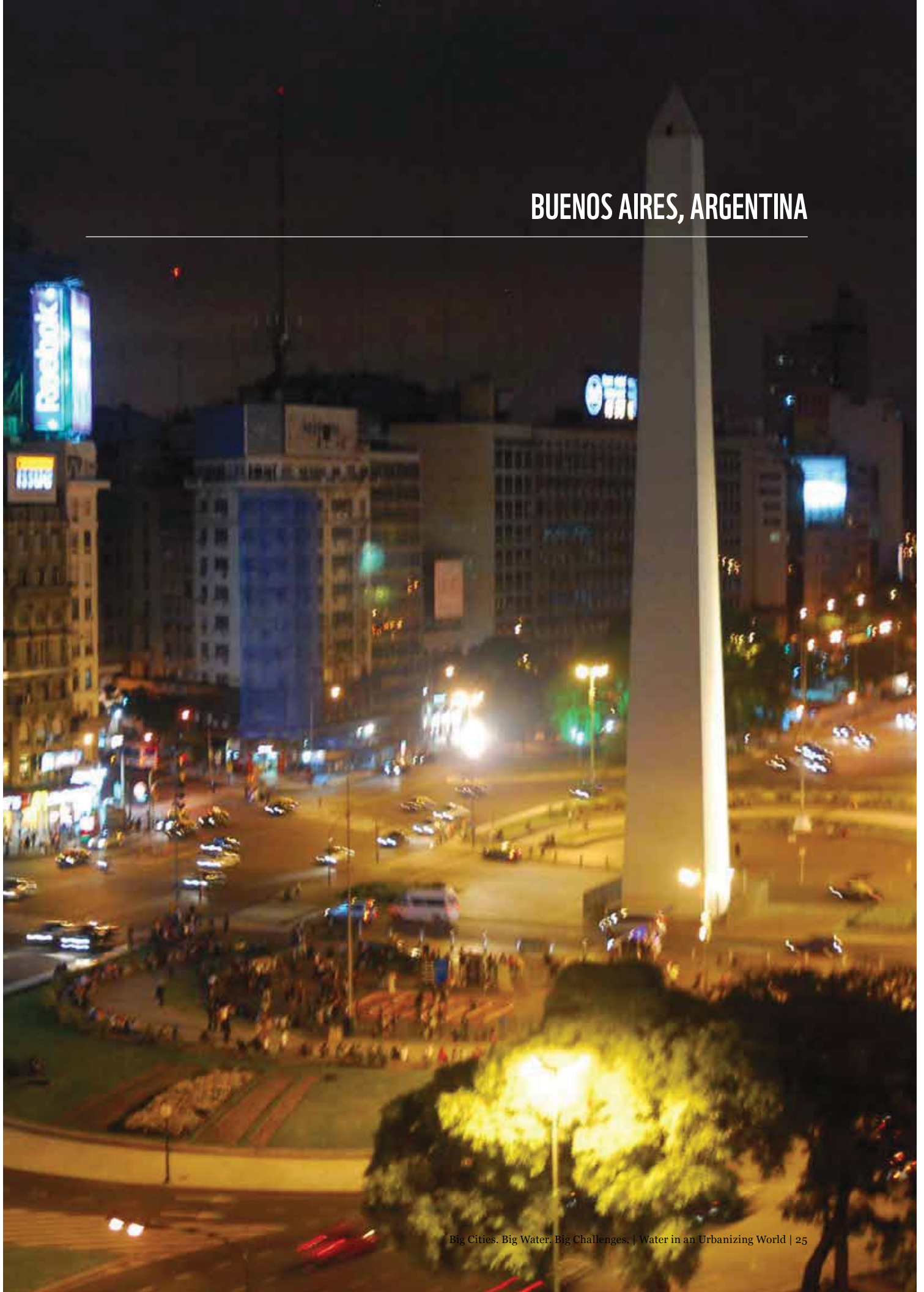
Hector Arias, WWF Mexico, at a meeting with local NGO's and local government representatives in Ojinaga, discussing the future of water resources. WWF – HSBC Wetland Programme 2003: Chihuahua Desert, Mexico.

WWF INVOLVEMENT

In partnership with La Fundación Gonzalo Río Arronte I.A.P (FGRA), WWF is developing new water management models for Mexico. The goal is to develop an adaptive management model for each Basin that involves all stakeholders (civil society, government, and academia) and restores/preserves the natural ecosystems to ensure the continuing provision of environmental services upon which all are dependent.¹⁴



BUENOS AIRES, ARGENTINA



BUENOS AIRES, ARGENTINA

GENERAL INFORMATION

Inhabitants	City: 2,891,082 Total metropolitan area: 12,801,364 (INDEC, 2010)
Population density	City: 14,185.9 people/km ² Metro (24 municipalities): 2,730.1 people/km ² (INDEC, 2010b)
Population growth	11.7% (since 2001 census) (INDEC, 2010)
GDP (estimated in 2008, \$bn at PPP)	US\$ 362 billion (rank 13) (Hawksworth et al., 2008)
Contribution to national GDP	40% ¹⁵
Area	City: 200 km ² Metro (24 municipalities): 3,600 km ² ¹⁶
Climate	Humid subtropical climate, winters of low precipitation and a prolonged hot season. Climate dominated by central semi-permanent high pressure center of the South Atlantic (frequent winds from NE)
Altitude	City: 25 m.a.s.l. ¹⁷
Mean temperature	Avg low: 13°C, Avg High: 22°C ¹⁸
Mean annual rainfall	101 mm ¹⁹

WATER STATISTICS

Domestic water use (liter per capita)	378 l – 400 l (Jordan et al., 2010; Garzon et al., 2009)
% households with water access	City: 99.9% Metro area: 68.1% (INDEC, 2001)
% water loss due to leakage in pipe systems	37% (Garzon et al., 2009)
Water price for domestic households	AYSA Tariff = fixed rate + metered consumption rate
% households with sewerage services	City: 99.5% Metro area: 39.2% (INDEC, 2001)
% wastewater treated	5.3% (Jordan et al., 2010)
Main water sources	La Plata River
Main water problems	Pollution Access to water network for poor

Greater Buenos Aires is officially comprised of the autonomous city of Buenos Aires and 24 municipalities in the state of Buenos Aires. The Argentinean Statistics Bureau (INDEC) acknowledges that six additional municipalities partially fall under the Greater Buenos Aires population, however this number is not reflected in the 2010 census data (INDEC, 2003). The official population of 12,801,364 inhabitants in Greater Buenos Aires accounts for 32% of Argentina's population and correspondingly contributes 40% to the national GDP.

While Argentina had tremendous economic growth and high per capita income in the 1990s, this came to a crashing halt in 2001 as the country defaulted and the corresponding financial, economic, and political crisis ensued (Jordan et al., 2010). However, already prior to the crisis, poverty was increasing in metropolitan Buenos Aires (more than 30% in 1995) and society became polarized with the middle class increasingly disappearing (Jordan et al., 2010). Poverty skyrocketed to 60% in the state of Buenos Aires and 20% in the city immediately after the crisis but is currently at 42.7% (28.3% in the suburban area) (Jordan et al., 2010; GobBsAs., 2004). It is estimated that 30% of urban land is made up of informal settlements, which has prevented the construc-

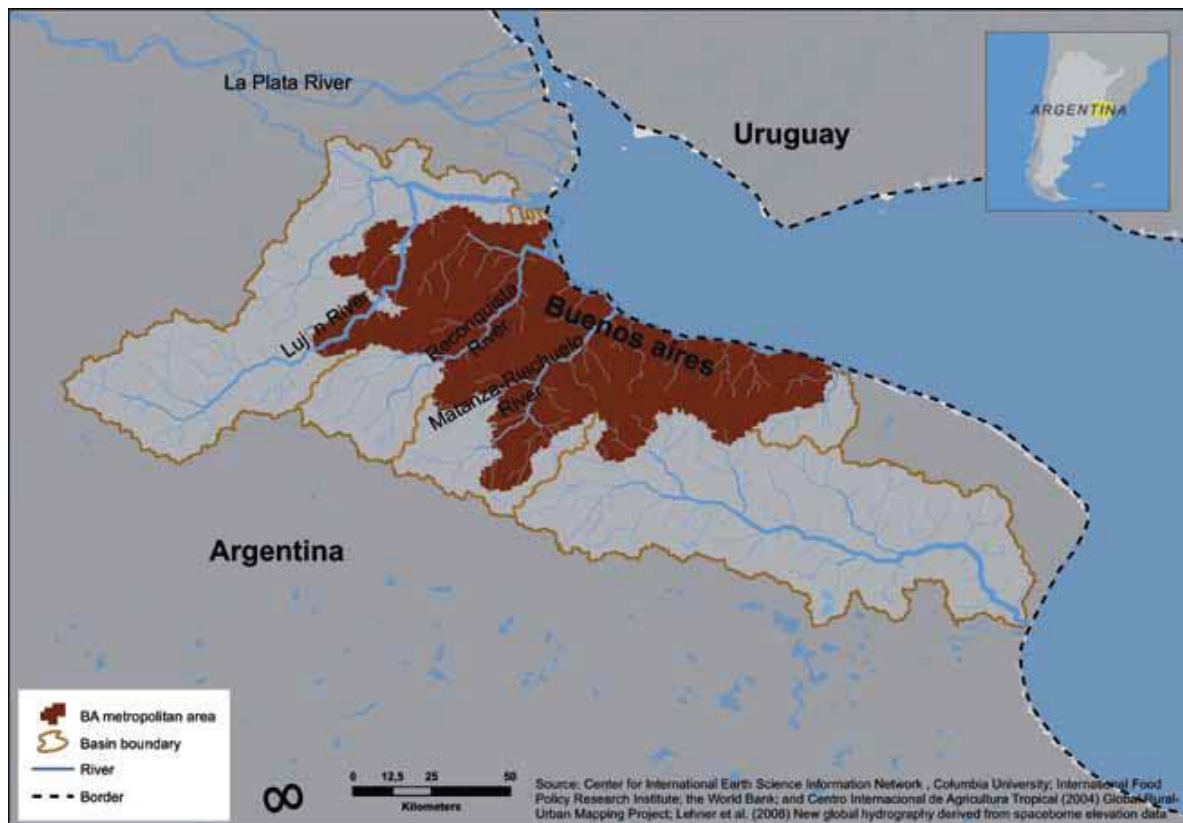
tion of water and sanitation networks. By law, water and sewage mains must be located on public land (under streets or sidewalks) (Almansi et al., 2010).

CATCHMENT AREA

Metropolitan Buenos Aires is found in the La Plata sub-basin, whose 130,200 km² make up part (4.2%) of the world's fifth largest river basin – the La Plata, extending over 3.1 million km², five countries (Argentina, Bolivia, Brazil, Paraguay, and Uruguay), almost 50 major cities, and supporting over 100 million inhabitants (UN WWAP, 2007). The mouth of the La Plata River is 230 km wide and separates Argentina from Uruguay. Within the La Plata sub-basin, factories found along the banks of metropolitan Buenos Aires are responsible for 98% of water abstraction (UN WWAP, 2007).

Though groundwater was historically extracted in metropolitan Buenos Aires, users are now supplied with treated water from the La Plata River. For those not connected to the water network, groundwater is extracted from the Pampean and Puelche aquifers (AABA, 2010; AySA).

The three main watercourses that form the base structure for the region's drainage network are the Luján, Reconquista, and Matanza-Riachuelo Rivers (AABA, 2010). The Luján River, 128 km, has the largest catchment area of nearly 3,300 km² and runs from southeast-northeast before discharging into the La Plata River (AABA, 2010). The Reconquista River is 82 km long, drains a catchment of 1,738 km² (the lower 40% is comprised of urban and semi-urban populations), and discharges into the Luján River. The Matanza-Riachuelo River (known as Riachuelo from its lower catchment) is 510 km long and eventually discharges into the La Plata River (AABA, 2010).



DRINKING WATER

Aguas y Saneamientos Argentinos (AySA) is the primary water service provider in the metropolitan area serving the city of Buenos Aires and 17 municipalities, while **Aguas Bonaerenses serves the remaining municipalities (information presented hereafter is for AySA as it is the predominant service provider).** **Almost 95 % of the water supply stems** from the La Plata River (4,442,065 m³ per day), while the rest is extracted from the ground (231,416 m³/day) and is treated at one of three plants (AySA, 2009). AySA is building two additional water treatment plants that will increase capacity by 947,040 m³ daily (AySA, 2009).

AySA's tariff system is based on a fixed rate plus metered consumption system. The rate structure classifies users according to category (residential or nonresidential), the zone where the building is located, and the services provided; sewer services cost twice the amount of the fixed fee for drinking water service; finally, low-income customers are eligible for a subsidy. As of 2007, only 12.8 % of the connections were billed under a metering system, thereby encouraging relatively high consumption (Garzon et al., 2009).

In 2010, AySA collected US\$103,478,000 from users and re-invested US\$195,144,000. AySA's users are 88 % residential (the majority of which are concentrated in the lowest socio-economic strata), 10.8 % nonresidential, and 1.2 % unowned land (Garzon et al., 2009).

WASTEWATER TREATMENT

AySA has four wastewater treatment systems that currently only treat 5.3 % of wastewater before discharging it into the La Plata River (Jordan et al., 2010). To improve this situation, AySA is in the midst of constructing another wastewater treatment plant "Del Bicentenario," which will increase the City's treatment capacity by 120,000 m³ per hour (currently 2,249,494 m³ per day is handled (AySA, 2009)).

WATER GOVERNANCE & MANAGEMENT

During the 1990s, the Argentine government privatized public services in order to improve service and attract foreign capital to finance the required investments; however the economic crisis of 2001 saw the State reclaim a centralized role in service provision (Almansi et al., 2010). The institutional structure for providing water and sewerage services in the city of Buenos Aires and the surrounding metropolitan area intends to separate institutional responsibilities for policymaking, sector planning, regulation, and service delivery.

In the Metropolitan Area, issues of inter-local relevance are under the authority of the National Government, the Autonomous City of Buenos Aires, the state of Buenos Aires, and the municipalities; however, the Autonomous City of Buenos Aires's government (Capital Federal) has the dominant role since "it has the largest territorial entity, population and a concentration of economic activities" (Jordan et al., 2010). Water and sanitation service planning is under an economically self-sufficient entity with public and private legal capacity, which receives 1.12 % of the rate collected for water and sanitation services (Garzon et al., 2009). The Water and Sanitation Regulatory Authority (ERAS) oversees the concessionaire's compliance with applicable regulations, supervising the quality of services, and protecting users' interests; it receives 1.55 % of the rate for water and sanitation service to fund its operations. The national government retains 90 % of AySA's stock (90 %) and AySA's employees hold the remaining 10 %.



MAIN WATER ISSUES

In addition to expanding service coverage to un-served areas and rehabilitating and renovating infrastructure, the main issues confronting metropolitan Buenos Aires are:

Pollution levels in Buenos Aires' rivers are so high that they could be considered "open sewers", which is particularly the case for Riacheuleo and the La Plata, making pollution the greatest environmental risk for the metropolitan area (UN WWAP, 2007; Jordan et al., 2010). The Riacheuleo, one of the most polluted water bodies in the world, has levels of Lead, Zinc and Chrome 50 times higher than the legal limit in Argentina; 25 % of this stems from industrial sewage and waste, the remaining 75 % originates from domestic sources (Jordan et al., 2010). The Riachuelo flows through a predominantly low-income area, with an above average frequency of children affected by intestinal diseases and the mortality caused by such infections (Jordan et al., 2010).



"OPEN SEWER" – MATANZA-RIACHUELO RIVER SOCIAL-ENVIRONMENTAL CONFLUENCE

Situated in the industrial nucleus of the extended Buenos Aires metropolitan area, the Matanza-Riachuelo River travels eighty kilometers through fourteen municipalities and part of the city of Buenos Aires, before emptying into the La Plata River. As such, it falls under national, provincial, and municipal jurisdictions. The Matanza-Riachuelo Basin (CMR) contains the most polluted water in the country and has been awarded the dubious distinction as one of the world's "Dirty 30," alongside such notorious sites as Chernobyl (Ukraine) and La Oroya (Peru), by the Blacksmith Institute.²⁰

The high levels of contamination in the CMR are the result of unregulated meat-processing and industrial activities which began almost 200 years ago and has continued uninterrupted to the present because of the absence of public policies to coordinate the more than fifty standards that exist across the diverse jurisdictions. The 3,000 industries situated along the length of the Riachuelo dump close to 88,500 m³ of waste daily, and the majority of them lack the capacity to enforce the necessary environmental standards or lack permits altogether. **Corruption and the lack of enforcement** capacity by state agencies continuously impairs efforts to reduce illegal dumping of industrial waste.

The contamination of the CMR is not just an environmental issue; more than 5 million people, of whom nearly 2 million are considered indigent or at-risk, live within the basin. Many of the people most affected by pollution are the residents of **shantytowns**, or "villas" constructed on riverbanks over old garbage dumps and fiscal lands too polluted to commercialize or develop. The vulnerability of this population (55 % of CMR's population is not connected to the sewer systems and 35 % lack access to safe drinking water) is exacerbated by the persistence of heavy metals and other pollutants in ground water. Similarly, the lack of sewerage and garbage collection services results in these wastes being deposited directly into the River, contributing to the vicious circle of water degradation and **human health risks**.

Flooding is a common problem for Argentina, but Buenos Aires is particularly at high risk as it is located in an area with low-relief energy, has high groundwater levels as it lies on the banks of the La Plata River, which also experiences water level increases due to rainy Southeast winds and ocean tides, and its canalized streams overflow after convective rains (Jordan et al., 2010; UN WWAP, 2007).

Overabstraction. From 1940 – 1991, groundwater was intensively extracted due to the rapid rise in urbanization and corresponding industrial and private consumption demands without proper land-use planning and infrastructure development (AABA, 2010). As a result of over-abstraction, reduced surface area to recharge water reserves, saltwater intrusion from low-lying areas of the estuary, the absence of sewer drainage pipes, and the elimination of untreated industrial effluent, aquifers, in particular free surface aquifers, experienced intense chemical deterioration (AABA, 2010).

Institutional Weakness. Though the water concession was meant to attract private companies who could bring the needed infrastructure and service upgrades, growth of service networks has been lower than planned, particularly in low-income sectors of metropolitan Buenos Aires (Jordan et al., 2010). Governance issues, institutional weaknesses and lack of control mechanisms are responsible for the failure of the concession (Jordan et al., 2010).

MANAGEMENT MEASURES IMPLEMENTED/ SOLUTIONS EXPLORED

Groundwater recharge. After the early 1990s, all groundwater-pumping stations were eliminated from the domestic water supply network and water from the La Plata River was used instead (AABA 2010). Aquifers were able to recover even further with the closure or decreased production from many industries as a result of Argentina's economic crisis in the late 1990s and early 2000s (AABA 2010).

Pollution. Through the Environmental Management Plan for the Matanza-Riachuelo River Basin, launched in 1995, the National Government, government of the Province of Buenos Aires, and the government of the City of Buenos Aires are attempting to address the causes of pollution in the metropolitan area (UN WWAP, 2007).

In June 2009, the World Bank approved a loan for US\$840 million in support of the “Matanza-Riachuelo Basin Sustainable Development project,” the single largest sanitation operation in Latin America. This is not the first time international money has flowed into Argentine coffers for CMR cleanup. In the 1990's, the Inter-American Development Bank (IDB) granted a multi-million dollar loan to the government, which promised to clean up the watershed in 1,000 days. Instead, the money was spent on consulting and distributed as subsidies/ social plans to marginal populations, without any measurable impact on the health of the waterway.

Citizen and NGO engagement. In 2004, a group of residents living in the CMR area filed a claim against the national government, the Province of Buenos Aires, the government of the Autonomous City of Buenos Aires, and 44 businesses for damages suffered as a result of pollution from the Matanza-Riachuelo River. The lawsuit resulted in a landmark decision from the Supreme Court in 2008, which ruled on the side of the residents and determined that the defendants were liable for restoration and future prevention of environmental damage in the river basin.²¹

The Environment and Natural Resources Foundation (FARN) took part in the case as a third party, along with various other civil society organizations. Throughout the entire process, FARN played a vital role in analyzing the defendants' submissions, submitting briefs and "amparos" (claims of constitutional violations), and coordinating the efforts of the different organizations. Since the ruling, in which the Supreme Court named FARN as a "permanent independent monitoring body for Riachuelo cleanup," the organization has maintained its leadership role. Alongside a number of other NGO's and WWF's Argentinean Associate – Fundacion Vida Silvestre Argentina (FVSA), FARN maintains the information flow related to the CMR cleanup and has staff dedicated to monitor the Riachuelo Case's evolution of the complex 8-point plan, which covers a wide range of issues (hydrological, environmental, territorial/ land-tenure, human health, access to information and public participation) and provide legal analysis and independent opinions on these issues to the implementing judge.²² FVSA actively encourages political engagement and commitment in restoring the CRM, including lobbying 2011's presidential candidates on this issue.

NAIROBI, KENYA

NAIROBI, KENYA

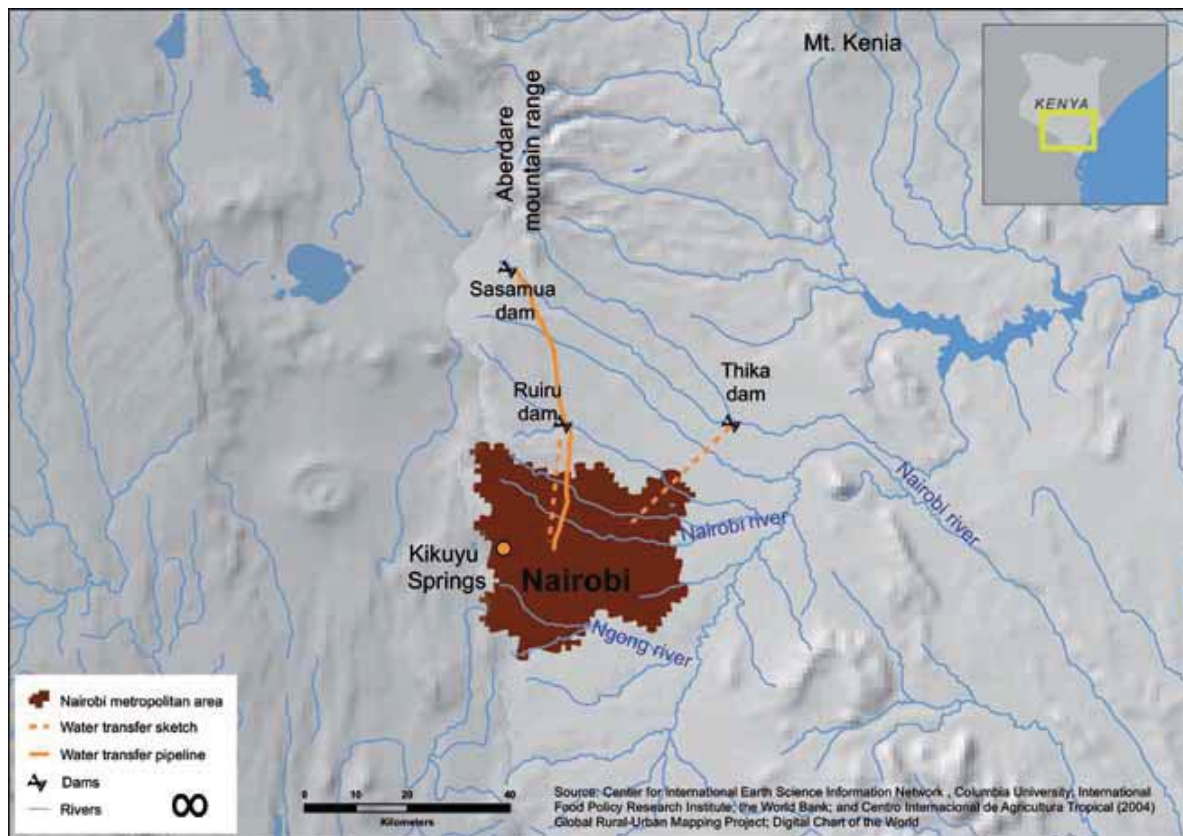
GENERAL INFORMATION	
Inhabitants	3,523,000 (2010) ²³
Population density	5,061 persons/km ²
Population growth	2.8 % estimated average annual population growth (2005-2015) (UN-HABITAT, 2010)
GDP (as estimated in 2008, \$bn at PPP)	US\$12 billion (rank 147) (Hawksworth et al., 2009)
Contribution to national GDP	60 % (Mafuta et al., 2011)
Area	696 km ² (UN-HABITAT, 2010)
Climate	Subtropical highland climate ²⁴
Altitude	1,650 m
Mean temperature	17.7 °C
Mean annual rainfall	1,024 mm ²⁵
WATER STATISTICS	
Water use (m ³ per capita)	700m ³ (in 2003) (Dudley & Stolton, 2003)
% households with water access	50% ²⁶
% water loss due to leakage in pipe systems and illegal connections	Up to 50 % (Dudley & Stolton, 2003)
Water price for domestic households	minimum 200 KSH (US\$ 2.10 ²⁷) per month when no meter is installed ²⁸
% households with sewerage services	48 % (GoK 2010a)
% wastewater treated	up to 80 % ²⁹
Main water sources	Rivers from the Aberdare Range Nairobi aquifer
Main water problems	Leakage due to over-aged infrastructure Lack of access to water supply in informal settlements Local authority lacks capacity

In the last century, Nairobi has rapidly grown from a small railway station in 1899 to one of Africa's 15 largest cities. Today it is the most populous city in East Africa with over 3.5 million inhabitants. The high percentage of informal settlements, as well as an average annual population growth of 2.8 % (though this has slowed down from the 4.5 % growth between 1995 and 2005 (UN-HABITAT, 2001)), has challenged the local authority's capacity to deal with water scarcity in an effective and sustainable way.

CATCHMENT AREA

Nairobi mainly receives its drinking water from rivers originating in the Aberdare Range and the Mt. Kenya water catchment area. The Aberdare Range, extending over 160 km, is situated north of Nairobi. Protecting the mountain rainforest ecosystem is of major importance for the city's water security. A healthy ecosystem guarantees that quality water is available for the metropolitan area, reducing the costs for treatment and the danger to human health. Although the Aberdare National Park (76,619 ha) is a protected area (IUCN Category II), the overall catchment area has experienced logging in the past (Dudley & Stolton, 2003). Recent studies however show a reduction of environmental degradation along with a 111 % increase of protected indigenous forest cover (62,000 ha in 2000 to 131,000 ha in 2010) (Mungai et al., 2011; Mafuta et al., 2011).

The Nairobi aquifer system (surface area of about 6,500 km²) is Nairobi's second water source (Mumma et al., 2011). It underlies much of the Nairobi metropolitan area, but recharges naturally from the southern Aberdares and the eastern Rift escarpment. Almost 50 % of the 986 km² recharge area is covered by forest or swamp, the rest is cultivated area (WRMA, 2010; Mafuta et al., 2011). The Nairobi aquifer system is predominantly vulnerable to depletion (Mumma et al., 2011); however, future degradation and extensive agricultural use could impact Nairobi's aquifer water quality.



DRINKING WATER

According to the Nairobi City Water and Sewerage Company, the water supply of 482,940 m³ per day stood against an estimated demand of 650,000 m³ per day for 3.5 million people in 2010. Currently, only 50 % of Nairobi's inhabitants have access to piped water and only 40 % receive water on a 24-hour basis. The rest obtain water from kiosks, vendors, and illegal connections.³⁰ In 2003, up to 50 % of piped water from the northern dams and reservoirs did not reach the city due to leaks in old pipes and illegal connections (Dudley & Stolton, 2003).

Ground and surface water both play an important role for Nairobi's water supply; the main water supply is transferred from dams north of Nairobi. Groundwater, which represented 21 % of the city's total water supply in 2002, is currently abstracted from the Nairobi aquifer suite (Mogaka, 2006, Mafuta, 2011).

Main source of water (% households in Nairobi)

Pond/Dam/ Lake	Piped	Stream	Spring/Well/ Borehole	Jabia/Rain harvested	other
0.3	75.7	0.1	7.2	0.2	16.5

(source: 2009 Kenya population and housing census, GoK 2010a)

1. Dams and springs:

Thika (or Ndakaini) Dam, Nairobi’s main water source, is located on the Eastern slopes of the Aberdares. It was completed in 1996 with a storage capacity of 77 million m³. The Thika Dam is further linked to Ngethu Water Works by a 4km long tunnel. The water works started operation in 1974, and was completed in 1995 with a capacity of 220,000 m³ per day. The water reaches Gigiri in Nairobi through a 36 km long pipeline. Water treatment is claimed to be 379,200 m³ per day. *Sasumua Dam* is also located in the Aberdares, the catchment stretching from the South Eastern to South Western slopes. The construction was completed in 1955, and extended in 1968, reaching a storage capacity of 15.9 million m³. It is connected to Kabete in Nairobi through a 60 km long pipeline, where the yield is 52,800 m³ per day. The *Dam on Ruiru River* was built in 1950 and designed for a storage capacity of 2.9 million m³ of water. Currently, the water is piped over 25 km to Kabete in Nairobi and the yield is 22,800 m³ per day. *The Kikuyu Springs*, three springs North West of Nairobi, were first opened in 1913. The spring water is piped to Nairobi over a distance of 10 km. The yield from Kikuyu Springs is 4,000 m³ per day.³¹

2. Nairobi Aquifer Suite:

There are approximately 4,800 boreholes in Nairobi, with an estimated daily supply of 65,000 m³ for domestic, 60,000 m³ of industrial water, 3,000 m³ for livestock uses and 28,000 m³ for irrigation in the Nairobi Aquifer Suite catchment area (WRMA, 2010).

WASTEWATER TREATMENT

The 2009 Census found out that only 48 % of households in Nairobi have access to waterborne sewerage (GoK, 2010a). Eighty percent of wastewater is treated in two facilities at Ruai/Dandora and Karinga in Nairobi³²; however, due to overaged infrastructure and overloading the treatment plants, regular breakdown of machines and equipment reduces the capacity to 74 % and 39 % respectively. Additionally, the Ruai treatment plant, does not meet the prescribed discharge standards for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). Effluents from the Ruai treatment plant are discharged into the Nairobi River (Mafuta et al., 2011).³³ Uncontrolled wastewater discharge, which does not meet environmental and discharge standards, is common in Nairobi (Mafuta et al., 2011).

WATER GOVERNANCE & MANAGEMENT

Over the last decade, water legislation and management have improved significantly in Nairobi. The “Water Act 2002” provides a comprehensive framework of regulations, institutions, and management bodies for water supply and wastewater treatment. National, regional, and local boards have been established for service, management, and supervision.

The following key institutions complete the framework provided in the Water Act 2002:

The Water Resources Management Authority (WRMA)	responsible for the sustainable management of water resources
Catchment Area Advisory Committees (CAAC)	advises WRMA on conservation, use and allocation of water resources in their catchments
Water Resources Users Association (WRUA)	provides a forum for conflict resolution and cooperative management of water resources in designated catchment areas
Water Services Regulatory Board (WSRB)	responsible for the regulation of water and sewerage services
Water Service Boards (WSBs)	responsible for the efficient and economic provision of water and sewerage services in their areas of jurisdiction
Water Service Providers (WSPs)	contracted by Water Service Boards to provide quality water and sewerage services
Water Services Regulatory Board (WSRB)	responsible for the regulation of water and sewerage services including development and maintenance of quality standards and issuance of licenses for service provision
Water Appeal Board	provides a mechanism for dispute resolution
Water Services Trust Fund (WSTF)	assists in financing the provision of water services to areas without capacity to develop adequate water services

(source: Water Act 2002, Mafuta, 2011)

The Nairobi City Water and Sewerage Company (NCWSC) provides water under contract from the Athi Water Services Board (AWSB). AWSB is a state corporation under the Ministry of Water and Irrigation constituted to provide water and sewerage services.³⁴

Main planning and strategic documents for water sustainability in Nairobi are the “Draft Strategic Plan for the Period 2010/11 to 2014/15” (by NCWSC and WRMA), “Preliminary Water Allocation Plan of the Nairobi Aquifer Suite: Long Term Water Resources Management Strategy”(by WRMAi), and ”Strategic Guidelines for Improving Water and Sanitation Services in Nairobi’s Informal Settlements, 2009 (by NCWSC and Athi Water Services Board).

MAIN WATER ISSUES

Nairobi faces severe water scarcity. Water demand exceeds water supply by about 200,000 m³ per day. Surface water is highly polluted. Up to 50% of drinking water is lost due to insufficient, outdated infrastructure and illegal connections. Only 50% of households have access to piped drinking water. Nairobi still has inadequate capacity to manage the increasing demand for water, especially in Nairobi’s informal settlements, where water is sold at water kiosks, often at a higher price than piped water. Untreated waste and wastewater both pose a danger to human health and lead to eutrophication, deoxygenation and habitat modification of riverine systems.

Old infrastructure causes leaks and losses. In 2003, about 50% of drinking water from the Aberdare Range did not reach the city (Dudley & Stolton, 2003). According to the AWSB, unaccounted for water has only been reduced from 65% to 42% since its inception. Most of the unaccounted for water is lost through illegal connections and technical losses due to underground leakage from the dilapidated piping system (Mufata et al., 2011).³⁵

Men with his bicycle bringing home plastic water containers, previously filled at a water depot/ storage tank. Water is a threatened resource and with population growth and expanding urbanization the pressure can only increase. For many cities time is running out. Protecting forests around water catchment areas is no longer a luxury but a necessity. Nairobi City, Kenya

Insufficient access to piped water. Currently only 50 % of Nairobi's inhabitants have access to piped water and 40 % receive water on a 24-hour basis.³⁶ Nairobi's informal settlements are most affected: an estimated 60 % of Nairobi's inhabitants live in informal settlements (NCWSC & AWSB, 2009). Nairobi has over 200 slum settlements with inadequate access to quality water and sanitation, and 44 % of Nairobi's residents live below the poverty line (SID, 2004). Insufficient connection to piped water often leads to **excessive water prices** at water kiosks. According to NCWSC and AWSB, about 22 % of residents of informal settlements have a household connection, while an estimated 75 % purchase their water mainly from resellers at water kiosks, operated by community groups or individual entrepreneurs, or push-cart vendors. Water is sold at about KSH 100 to 250 per m³ (US\$ 1.1 to 2.6). This price is above NCWSC's average water price of KSH 45/m³ (US\$ 0.5) and well above the official price for water in informal settlements of KSH 10-15/m³ (US\$ 0.1 –0.16). Resellers add their own margins and the rate is not always accurately billed. Consequently, informal settlement residents are the highest-paying consumers in the city per cubic meter, and on average, spend a higher share of their monthly income on water. Based on the estimated average monthly income in Nairobi's informal settlements³⁷ one cubic meter of water from a kiosk accounts for 3-8 % of the monthly income instead of 0.5 % when paying the official water tariff (NCWSC & AWSB, 2009).



Water quality. The Nairobi aquifer groundwater quality is generally good. It meets the drinking water standards for most constituents, except for fluoride (Foster & Tuinhof, 2005). According to NCWSC, water derived from Kikuyu Springs is only treated by chlorination.³⁸ The rest of the surface water, which currently accounts for the bulk of Nairobi's water, is heavily polluted and therefore has high treatment costs. Pollutants are agro-chemicals, heavy metals, microbial, and persistent organic pollutants (UNEP, 2007). Degradation of upstream ecosystems results in poor water quality and **rising costs for water treatment**. At Sasumua Dam for example, natural water purification provided by a healthy ecosystem would be less expensive than the physical and chemical purification that is actually necessary (Msafiri, 2008). The NCWSC currently spends US\$170,000 monthly on chemicals and US\$110,000 annually for de-sludging the Sasumua Dam (Mufata et al., 2011).



Heavily polluted stream used as a sewage drain. Nairobi, Kenya



Implementation problems. Although the water sector reform puts new management rules in place that provides a legislative framework for sustainable approaches, implementation challenges still persist in Nairobi. Unplanned construction, limited resources, high costs of operation and maintenance, local political interference, high debts and liabilities, lack of autonomy to make major investments, inequitable distribution of water, sewage used by farmers with subsequent public health implications, industrial waste discharge into the sewer network by industries and other consumers, and financial demands from riparian communities further endanger Nairobi's water security (Muirui & Kaseve, 2008; Mufata et al., 2011).

Climate Change. At present, there are no overarching policies or laws explicitly for the management of climate change. There is not much doubt that climate change already affects and will further affect Kenya in the future (GoK, 2010b). The 2010 National Climate Change Response Strategy (NCCRS) has outlined the ways in which the water sector should address adaptation and mitigation. More detailed implementation plans, however, will be required (Mumma et al., 2011).

MANAGEMENT MEASURES IMPLEMENTED/SOLUTIONS EXPLORED

New boreholes and dams. New infrastructure projects, both for the abstraction of surface and groundwater, are planned. WRMA has identified 347 additional boreholes in Kikuyu, Karen, Ongata-Rongat, Thika, and wetland areas with a density of 6–20 boreholes per km². AWSB has developed plans for new dams at Maragua and Ruiru to increase the daily water yield (Mufata et al., 2011).

Management measures for informal settlements. In 2009, the NCWSC and AWSB formulated water management strategies to improve water supply in informal settlements (NCWSC & AWSB 2009). These measures include: network intensification – AWSB and NCWSC, together with community partners, will ensure the intensification of formal networks in both water supply and sewerage and remove informal and illegal water networks – water supply in bulk and introduction of bulk meters; introduction of meter chambers with selected accountable community partners to supervise the process; upgrading of pipes to reduce leakages and bursts and prevent water contamination; facilitation of improved water kiosks that provide safety of the meters and facilitate a higher-quality service by individual or community operators (Mufata et al., 2011).

Guidelines for groundwater abstraction. In 2006, a set of guidelines were established by WRMA to protect aquifers and control groundwater abstraction (WRMA, 2006; Mufata et al., 2011). The guidelines include: rainwater harvesting undertaken parallel to groundwater extraction and consideration of maximum pump motor size, density of existing boreholes, and potential for deeper aquifers when new permits are granted. No permit will be granted in notified areas.

ALTERNATIVE SUSTAINABLE APPROACHES?

The rapid and largely unplanned development of Nairobi City, along with overaged and dilapidated water infrastructure, and the past degradation of the upstream watershed endangers water quality and supply. The Minister of Water and Irrigation has calculated that the cost for protecting the catchment area and building infrastructure would amount to the equivalent of US\$ 30–70 million per year; however, these costs cannot be covered by traditional revenue collection from water users (Hoff, 2008).

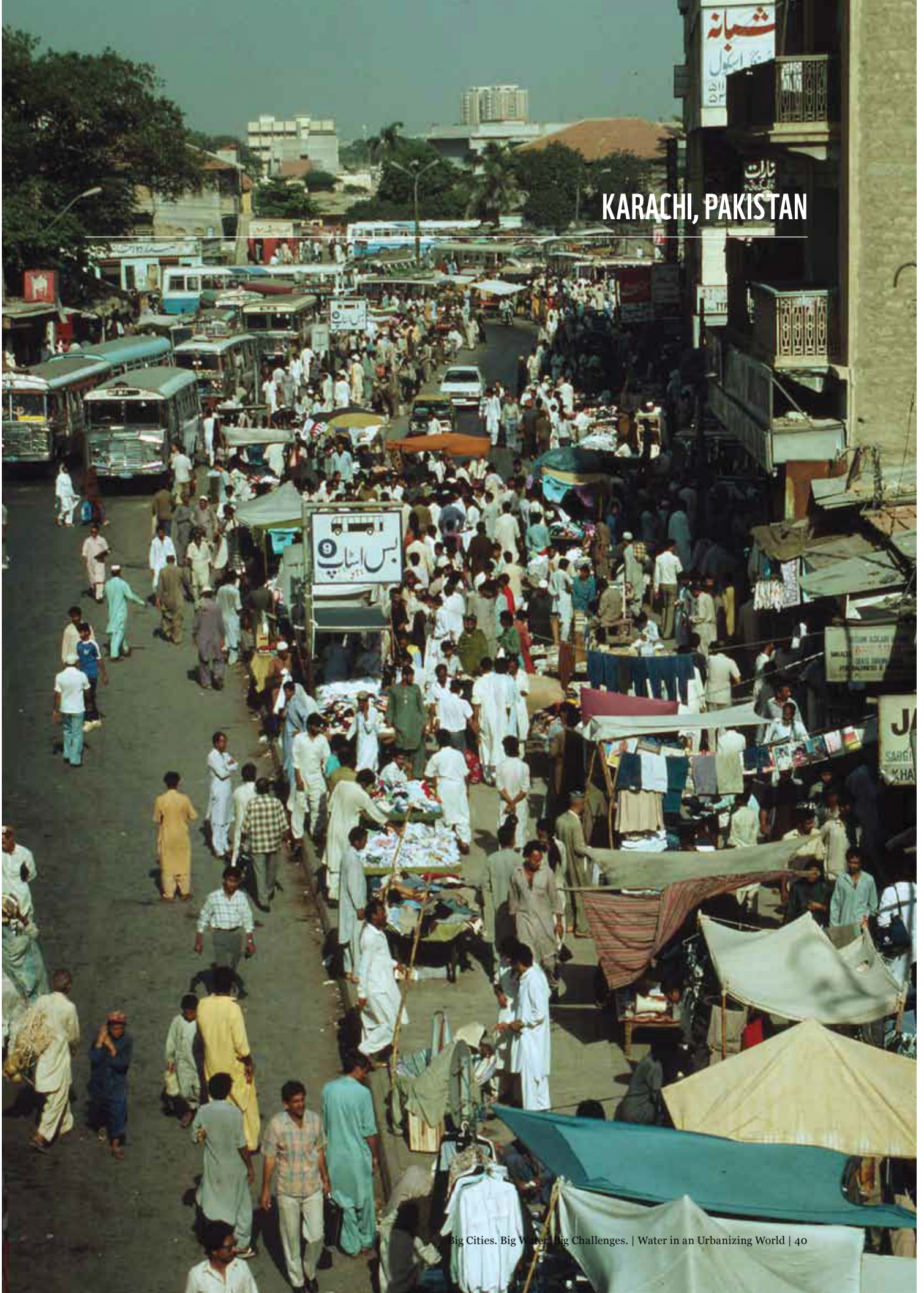
There are approaches that take the increased use of ‘green water’ into consideration: ‘Green water’, the largest fresh water resource on earth, is defined as rainwater that is stored in the soil and that is available for uptake by plants (Li et al, 2010). This resource can be increased by reducing runoff and evaporation from the soil, leading to a larger amount of water available for crops and also to more water that can be used downstream (the so called ‘blue water’). In the Tana Basin, including the Aberdares and Mount Kenya region, innovative soil- and water management techniques applied by farmers upstream could improve water quality and increase water available downstream.³⁹

A Payment For Environmental Services (PES) initiative has been implemented successfully in Kenya’s Lake Naivasha catchment area, where upstream farmers are compensated for watershed protection and safeguarding water quality. It is presented as a possible model for Nairobi and other megacities in the conclusion chapter.

Nairobi suburb



KARACHI, PAKISTAN



KARACHI, PAKISTAN

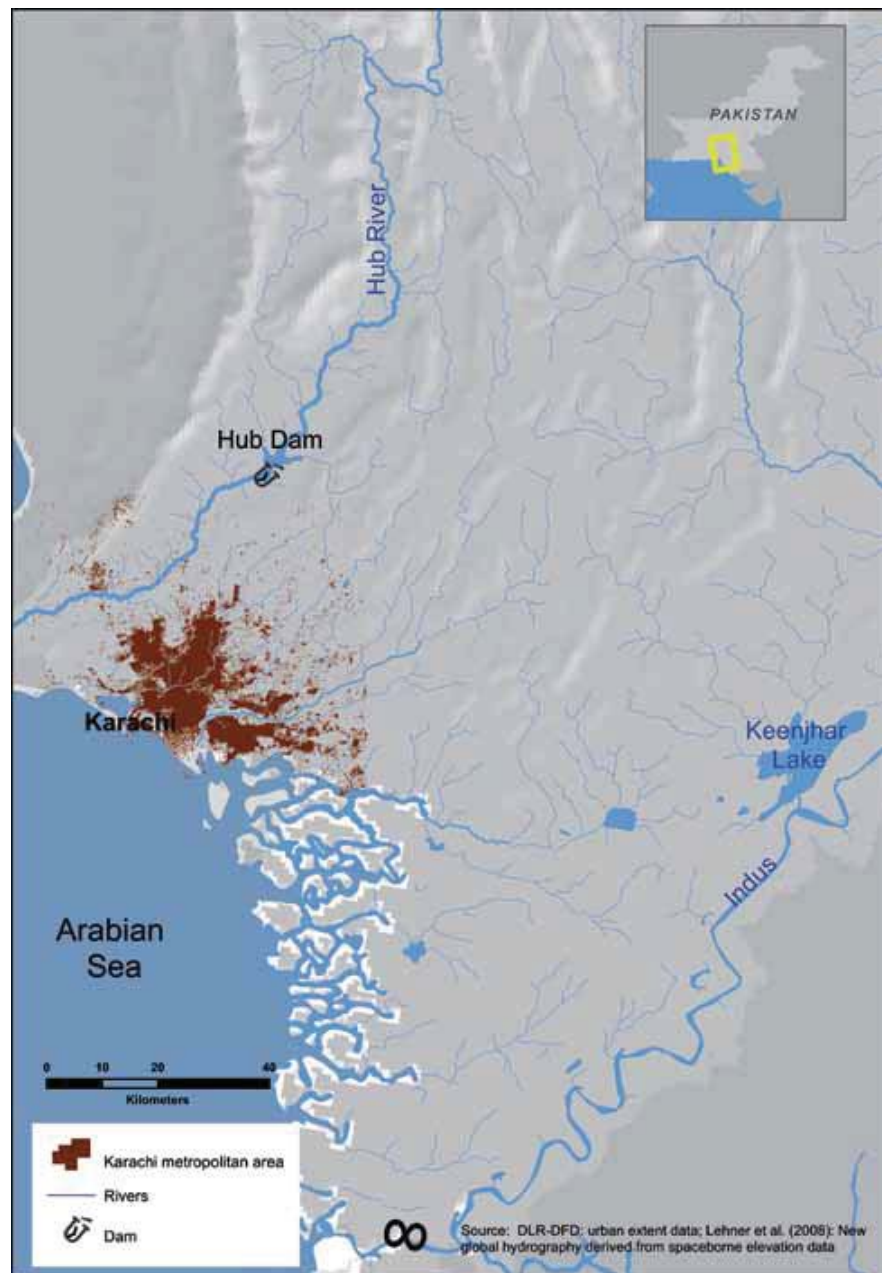
GENERAL INFORMATION	
Inhabitants	18,000,000 ⁴⁰
Population density	4,115 persons/km ² ⁴¹
Population growth	5 % growth per year, mainly on account of rural-urban internal migration ⁴²
GDP (as estimated in 2008, \$bn at PPP)	US\$ 78 billion (rank 78), (Hawksworth et al., 2009)
Contribution to national GDP	20 % (ADB 2005)
Area	3,527 km ² ⁴³
Climate	Arid with low levels of annual rainfall, the bulk of which occurs during the July-August monsoon season. ⁴⁴
Altitude	8m AMSL ⁴⁵
Mean temperature	26.1°C ⁴⁶
Mean annual rainfall	167.6 mm ⁴⁷
WATER STATISTICS	
Domestic water use (liter per capita)	165 l/person/day (Economist Intelligence Unit, 2011)
% households with water access	60 % (Master Plan Group of Offices, 2007; ADB, 2004)
% water loss due to leakage in pipe systems	25 % (Economist Intelligence Unit, 2011)
Water price for domestic households	Typical domestic tariff based on 20 m ³ /month (excludes any fixed charge) \$2.63 (ADB 2007) (KW&SB has a complex tariff structure ⁴⁸)
% households with sewerage services	57 % (Economist Intelligence Unit, 2011)
% wastewater treated	22 % (Economist Intelligence Unit, 2011)
Main water sources	Indus River Hub Reservoir Dumlottee Reservoir
Main water Problems	Supply problems and contamination Industrial pollution Revenue recovery Climate change

Karachi, situated in the far south of Pakistan and on the coast of the Arabian Sea, is Pakistan's most populated city and largest industrial centre. Its water and sewerage infrastructure has not been able to keep up with population growth in the last decades, which has consequently caused water scarcity and even riots in certain areas (Kamal et al., 2004). Over 50 % of Karachi's population lives in *katchi abadis*, informal slum settlements (Kamal et al., 2004).

CATCHMENT AREA

At present, Karachi receives water mainly from two sources: the Indus River to the east of the city and the Hub reservoir, a large water storage reservoir constructed on the Hub River in 1981, flowing west of the city. The Hub Reservoir was not able to supply water for several years in the late 1990s and early 2000s as the dam's catchment area was dry during the monsoon season. A large area of the Hub River catchment near Karachi is protected, including a Ramsar Wetlands of International Importance at the Hub Dam Wildlife Sanctuary. Keenjhar Lake, providing much of Karachi's water from the Indus, is also a Ramsar site.

The semi-arid environment of the Indus Basin is home to more than a quarter of a billion people (Mustafa, 2007). It features the largest contiguous surface irrigation system on Earth, irrigating 80 % of Pakistan's 21.5 million ha of agricultural land (Wong et al., 2007); in Pakistan, 22 % of the GDP is due to agriculture (ICIMOD, 2010). Being the region's lifeline, both on the Indian and the Pakistani side, the need for a regulating agreement over the distribution of the precious water resource was recognized, and the Indus Treaty was signed in 1960.





DRINKING WATER

According to the Karachi Water and Sewerage Board (KW&SB), the Indus supplies 25.4 m³/s of water, the Hub Reservoir 4.4m³/s and a remainder comes from the Dumlottee Reservoir fed by wells on the banks of the Malir River (0.9m³/s). Altogether, Karachi's water supply system receives an inflow of 30 m³/s, water demand was at 33 m³/s in 2005, resulting in a water supply shortfall. Additionally, the water distribution system in Karachi is, on average, about 40 years old, with many corroded pipes that disrupt effective transmission (Economist Intelligence Unit, 2011). Thus, an additional 35 % of the water supplied gets lost due to leakages and large scale unauthorized diversion or thefts (Master Plan Group of Offices, 2007).

Under the present conditions, water supply is irregular and inequitable, some areas receiving more water than others, and some too little to meet needs. Water is supplied only for a few hours at very low pressure (Master Plan Group of Offices, 2007). Apart from the piped supply connections, water vending through commercial water tankers also exists. Many inhabitants rely on water vendors for their daily water supply, as municipal water does not reach their areas. According to estimates by the Karachi Water Tanker Association, the tankers that supply water from KW&SB-designated hydrants account for about 8 % of the total water supply (Ahmed, 2009).

WASTEWATER TREATMENT

The sewerage system has had very little maintenance since the 1960s (ADB, 2007), and the three existing treatment plants serving the city operate at about 50 % efficiency, experiencing blocked pipes and frequent mechanical failure (Economist Intelligence Unit, 2011). There is a general recognition that the sewerage system is in even greater disrepair than the water system (ADB 2007).

Only 22 % of municipal wastewater is treated (Economist Intelligence Unit 2011). More than 40 % of Karachi's population is not connected to the sewerage system at all, and there is little separation of municipal wastewater from industrial effluent, which both flow directly into open drains and then into natural water bodies draining into the Arabian Sea (WWF Pakistan, 2007). Two of the biggest industrial estates in Pakistan, both located in Karachi, have no effluent treatment plant and the waste containing hazardous materials, heavy metals, oil etc. is discharged into Karachi's rivers and the already polluted harbor (WWF Pakistan, 2007).

WATER GOVERNANCE & MANAGEMENT

The authority responsible for Karachi's water management is the entirely government-owned Karachi Water and Sewerage Board (KW&SB). The Karachi Water & Sewage Board Act (1996) and Sindh Local Government Ordinance (SLGO) (2002) regulate water provision and wastewater treatment. KW&SB's estimated budget for 2011-2012 is US\$ 304 million⁴⁹ - the budget of the City District Government Karachi (CDGK) for the same time is US\$ 820 million⁵⁰.

In 2007, the Health Services Academy under the Ministry of Health published Quality Drinking Water Standards for Pakistan, and a National Drinking Water Policy was passed in 2009. Lab facilities monitor chlorination and maintain quality control according to WHO guidelines at all water treatment plants. In addition, the KW&SB Central Lab monitors the bacteriological quality of city water by collection and testing 900 – 1000 samples per month from the city's distribution system. Water not fit for domestic use is given treatment through sedimentation and filtration and disinfected by means of pre and post-filtration chlorination.

MAIN WATER ISSUES

While a comprehensive national policy and institutional framework for environmental management is in place, there are significant **weaknesses in administrative and implementation capacity**. The result is that, while an appropriate and necessary administrative capacity exists on paper, its effectiveness is seriously curtailed in practice (WWF Pakistan, 2007).

Supply problems and contamination. More than 50 % of Karachi's population lives in *katchi abadis* (informal slum settlements) and most of them face severe shortage of water as well as the lack of proper sewerage systems (ADB, 2007). The wastewater generated by the population that does not have a sewerage connection is disposed of in local areas, generally to the storm water drainage system and then directly to open drains. This creates significant localized sanitation and pollution problems, especially in times of heavy rain (ADB, 2007). Sewage seeping into shallow groundwater often infiltrates into the water supply system through leaky pipes. As a result, Karachi and other cities in Pakistan were hit by major outbreaks of waterborne epidemics in 2006 (ADB, 2007). According to health experts, around 30,000 people, most of them children, die each year in the city due to consumption of contaminated water⁵¹.

Many illegal suppliers obtain connections to the public networks through fraudulent means. According to KW&SB officials, water is being stolen from around 150 illegal hydrants drawing over 113,000 m³ of water from the main pipelines every day, not only causing acute water shortage, but also massive revenue losses of over US\$ 15 million annually. In some areas, water is diverted by businessmen who sell at exorbitant prices to people who have no other option but to buy it for up to twelve times the official price⁵².

Revenue recovery is also a major problem. Although KW&SB has a complex tariff system in place based on customer (domestic, industrial, offices etc.), plot area, measured supply and annual rental value, among other factors, a substantial number of consumers do not pay. Weak enforcement of payment recovery does not allow effective generation of revenue (Ahmed, 2009). The ADB estimated a collection efficiency of 25 % in 2007.

Industrial pollution. Approximately 435 million m³ of wastewater is produced annually in Karachi, corresponding to about 70 % of water provided to households and industry. Of this, only around 20 % is treated, indicating that 340 million m³ of untreated wastewater is discharged directly into the Arabian Sea per year (ADB 2007). In 2007, WWF found that water samples from the Karachi harbor showed trace metals in concentrations far exceeding any other major harbor in the world (WWF Pakistan, 2007). The pollution load on Karachi's two rivers, the Lyari and the Malir, and on the coastal ecosystem is immense. The local marine environment is highly polluted and puts the mangrove swamp ecosystem under severe threat. Trace metal concentrations in fish and shellfish harvested from Karachi's coastal areas are very high (Kamal et al., 2004), and industrial pollution discharges combined with mangrove forest ecosystem degradation are resulting in a decrease in shrimp and fish production (WWF Pakistan 2007).

There is no regular monitoring program to assess the water quality of the surface and groundwater bodies and there is no surface water quality standard in Pakistan. A comparison of the quality of surface water with the effluent discharge standard clearly demonstrates the extent of pollution in the water bodies due to the discharge of industrial and municipal effluent (WWF Pakistan 2007).



Climate change. The Indus River is extremely sensitive to climate change due to the high portion of its flow derived from glaciers (Wong et al., 2007). Snow and glacial melt contribute more than half of the annual average flow of the Indus River and around 50 % of its tributaries (ICIMOD, 2010), more than any other Asian river. Climate change, causing glacial retreat, is already impacting the glacial regime in the basin (ICIMOD, 2010). Agriculture and other economic activities rely heavily on this water, and changes in water availability can have serious impacts on the lives and livelihoods of millions of people living in the Indus basin, including Karachi's inhabitants at the end of the watercourse.

Extreme climate events can have serious impacts on Karachi's water supply. While droughts, such as in 1999-2001, cause water shortages in the city, extreme monsoon rainfalls can cause flooding and ensuing outbreaks of waterborne diseases due to decrepit and blocked sewage systems unable to absorb storm water.

MANAGEMENT MEASURES IMPLEMENTED/SOLUTIONS EXPLORED

Infrastructure and engineering solutions have been the predominant focus to resolve water issues in the past. However, the Karachi Strategic Development Plan places **water demand management** high on its agenda for managing the city's future water supply. Strengthening and replacing affected infrastructure in order to reduce losses, energy use, and bulk water supply requirements are identified as top priority. Approaches are called for such as consistent water metering, public education on water conservation, harvesting rainwater or providing alternatives to piped water for uses that do not require drinking water quality.

There has been little notable effort on behalf of the authorities to involve local communities and residents in water supply and sewerage solutions. However, there are examples of how technology, government support, government collaboration, community efforts and users paying at least some costs of infrastructure and delivery service has led to projects that may be emulated elsewhere. An example of such an effort is the well-known Orangi Pilot Project (Kamal et al., 2004).

The Orangi Pilot Project (OPP)

The Orangi Pilot project in Karachi gives residents in poor communities the resources and engineering expertise to help solve their own environmental challenges. The project was started by an NGO in the 1980s in Orangi Town, a cluster of low-income settlements in Karachi with a population of 1.2 million. The project's initial focus was sewer improvements. Residents constructed sewer channels to collect waste from their homes, and these were then connected to neighborhood channels, which ultimately discharged into the municipal trunk sewer. Infant mortality rates fell from 130 to 40 per 1,000 live births, with 90 % of the population involved (ADB, 2007). Within 10 years, the program had expanded to cover not only environmental challenges, but had also led to the establishment of schools, health clinics, women's work centres, stores and a credit organisation to finance further projects. Today, the Orangi project model is being replicated in other cities in Pakistan, as well as Sri Lanka, India, Nepal and South Africa⁵³.

There is an urgent need for the introduction of **integrated water resource management** concepts. Future water shortages and wastewater disposal problems exacerbated by the city's exploding population and causing rapid environmental deterioration call for concerted efforts to introduce integrated approaches.

Some efforts have been made in this direction; the Hisaar Foundation, a non-profit-organization working on water, food and livelihood security, founded the Karachi Water Partnership (KWP) in 2007. Through building local water partnerships, this citizen driven initiative coordinates stakeholder forums that facilitate government/citizen collaborations in managing water issues at a local level. KWP promotes consumer behavior change, ownership of water resources, sharing of information technology, and supports local government action⁵⁴.

Although the **protected areas** around the and at Keenjhar Lake focus mainly on wildlife, given Karachi's difficulties with supplying its citizens with constant freshwater, there is the possibility for management to also play a role in securing waters for the city (Dudley & Stolton, 2003).

WWF INVOLVEMENT

WWF's Indus Ecoregion Conservation Programme works to conserve the rich biological diversity of the Indus Basin, identified as one of the world's forty biologically most significant ecoregions, through local community livelihood improvement. Currently, it is in the first five-year (April 2007–March 2012) implementation phase of a 50-year vision and is being implemented by WWF Pakistan in close collaboration with the Government of Sindh, selected Civil Society Organisations, and local communities. Additionally, Kheenjhar Lake, one of Karachi's main Indus water reservoirs and a Ramsar site, is an important WWF project site⁵⁵.

KOLKATA, INDIA



KOLKATA, INDIA

GENERAL INFORMATION	
Inhabitants	City: 5,100,000 total metropolitan area: 15,420,000 ⁵⁶
Population density	24,760/ km ² ⁵⁷
Population growth	4.1 % annually ⁵⁸
GDP (as estimated in 2008, \$bn at PPP)	US\$ 104 billion (Rank 61) (Hawsworth et al., 2009),
Contribution to national GDP	3.08 % ⁵⁹
Area	1851 km ² , 40 % of which is rural area (WWF India, 2011)
Climate	Tropical monsoon climate (Southwest Monsoon from June to September) ⁶⁰
Altitude	6.4 m asl ⁶¹
Mean temperature	26°C ⁶²
Mean annual rainfall	152 mm ⁶³
WATER STATISTICS	
Domestic water use (liter per capita)	130 (ADB, 2007)
% households with water access	79.0 % (ADB, 2007)
% water loss due to leakage in pipe systems	35 % (Economist Intelligence Unit 2011, ADB 2007)
Water price for domestic households	Domestic: one water supply connection per premise is unbilled. Commercial flatrate between US\$ 11.60 and US\$ 66 per month ⁶⁴ Additional water can be bought through the KMC: US\$ 0.15/ m ³ (domestic) US\$ 0.33/m ³ (industrial, commercial and institutional) ⁶⁵
% households with sewerage services	52.0 % (Economist Intelligence Unit, 2011)
% wastewater treated	20.0 % (Economist Intelligence Unit, 2011)
Main water sources	Surface water from the Hooghly branch of the Ganges Groundwater from deep and hand tube wells
Main water problems	Water use inefficiency Pollution Flooding Ecosystem destruction International dispute

Until the mid- 1980's, Kolkata was India's most populous city before Mumbai took over this distinction. Among India's cities, Kolkata contributes the third-largest share to the national GDP, owing to its IT sector, which is growing at 70 % annually – twice the national average⁶⁶, and it boasts India's second largest stock exchange after Mumbai. The metropolitan area includes Kolkata, the industrial city of Howrah on the west bank of the Hooghly River, the city of Chandernagore to the North and their associated suburban areas.

CATCHMENT AREA

The majority of Greater Kolkata's water is treated surface water from the Hooghly branch of the River Ganges (Dudley & Stolton, 2003), along with groundwater from various deep and hand tube wells and private pumps (Segane, 2000). The river Hooghly is a distributary of the parent river Ganges, whose source is in the Himalayas. The Ganges basin has a population of more than 400 million, making it the most populated river basin in the world, and is part of the composite Ganges-Brahmaputra-Meghna basin draining an area of 1,086,000 km².⁶⁷ In its lower stretch, the Ganges merges with the Brahmaputra through a complex system of common distributaries into the Bay of Bengal.



DRINKING WATER

The drinking water for Kolkata Metropolitan Area (KMA) is treated in several water treatment plants with a total capacity of slightly more than 1.4 million m³ per day located in different parts of KMA.⁶⁸ Kolkata Municipal Corporation (KMC) claims that 94 % of the city's households are connected to piped water and that water is supplied continuously for up to 20 hours per day. However, a study by the Asian Development Bank (ADB) from 2007 on the water utilities in India found that only 74 % of households are connected and that the average time of daily uninterrupted water supply is 8.3 hours. The households not connected to the water supply system mainly extract groundwater through private wells and pumps.⁶⁹ There is no pricing system for domestic water consumption.

WASTEWATER

The city of Howrah discharges its sewage mainly into the Hooghly River. Wastewater of Kolkata is discharged into East Kolkata Wetlands (EKW) – 12,500 ha of marshy wetlands connected to the Hooghly branch of the Ganges and eventually flowing into the Sundarbans mangrove forests. After the EKW's former source of inflow from the Hooghly River became increasingly clogged due to silt accumulation in the past decades, its main source of influx today is Kolkata's sewage system. Since the late nineteenth century, the city's sewage water flow has led to the development of a unique ecosystem that organically treats the discharge, which is then used for fish farming and agriculture (WWF India, 2010). Treating about 2.8 billion liters of sewage from the city, EKW hosts the largest sewage-fed fishpond system in the world (WWF India, 2011). A number of studies have shown that this is a very effective system for organically treating wastewater and reusing it. For instance, the wetlands are able to lower the coliform count in sewage water by 96 % (Chaudhuri & Thakur, 2006) even as they produce a rich harvest of food for the city. In 2002, the East Kolkata Wetlands were designated a "Wetland of International Importance" under the Ramsar Convention.

WATER GOVERNANCE & MANAGEMENT

The metropolitan area's water is managed by three authorities (Kolkata Municipal Corporation, Howrah Municipal Corporation and Chandernagore Municipal Corporation), with the Kolkata Metropolitan Water and Sanitation Authority responsible for the development and improvement of water and sanitation facilities for Greater Kolkata.

Kolkata has a water quality code in place covering pollutants in surface water and has standards for key pollutants in drinking water. Water quality standards for industry are also enforced, and the state government authorities regularly monitor water quality in the Hooghly (Economist Intelligence Unit 2011). Howrah Municipal Corporation (HMC) has a modern water testing lab for drinking water⁷⁰.

MAIN WATER ISSUES

Inefficient water use. The strategy of supplying water essentially for free to citizens has led to a huge wastage of water in Kolkata. According to Majumdar & Gupta (2007), the issue of conservation is completely neglected, which over time has also led to mounting government subsidies on water. An analysis of the decade between 1992–2002 revealed that the expenditure for water supply and sewerage increased five times, whereas revenues only doubled.

The policy of not pricing water for domestic use has certainly earned the authorities criticism for sending wrong price signals to consumers and thus promoting wastage (e.g. ADB, 2007, McKenzie & Ray, 2009). The consequence of underpricing, along with KMC's overstaffing and the high levels of water that is unaccounted for, is that KMC can hardly cover maintenance costs or provide capital for network improvement through tariff revenues. KMC's recovery of operational costs, at only 15%, is one of the lowest among Indian cities (McKenzie & Ray, 2009).

Pollution. Groundwater, being the secondary source of fresh water in the KMA, has been extracted for domestic and agricultural use in large quantities in areas more remote from the river (Chakravarti, undated). Kolkata and the Ganges delta lie in a geological zone with naturally occurring arsenic in deeper layers of the bedrock. Thus, groundwater naturally contains varying levels of arsenic. However, levels above the WHO's recommended maximum of 10µg/l of arsenic were found in groundwater samples in 65 of 100 sampled wards in Kolkata over a twenty-year study period (Chakraborti et al., 2009). The natural occurrence of this carcinogenic element in the underground aquifer is exacerbated by the over-extraction of groundwater, which causes the water table to fall and forces residents to keep digging ever deeper tube wells (Segane, 2000). Over-extraction of groundwater and reduced rate of aquifer recharge also causes ground subsidence.^{71,72}

A 2003 survey of 1,000 locations in Kolkata found that 87% of water reservoirs serving residential buildings and 63% of taps had high levels of fecal contamination (McKenzie & Ray, 2009). Fecal contamination of drinking water is often associated with untreated sewage runoff seeping into the ground. Polluted groundwater can enter municipal water distribution systems through leaking and cracked pipes and causes shallow wells to become contaminated.

Flooding. As urbanization changes the land-use in Kolkata, the natural drainage has become altered, which has caused variations in the micro-topography of the city. In fact, the original drainage and canal system of the city that took excess storm water and drained into the river for naturally treating the water has become ineffective since the sewers and drains were constantly overcharged. Also, the number of culverts and small bridges that are built across the drainage system or land filling them to create space has led to frequent flooding⁷³. This is also because the planning process fails to take into account the natural gradients based drainage patterns that exist within the city (WWF India, 2011). The current sewerage system is not capable of handling rainfall intensity greater than 6 mm per hour, thus during the monsoon season, large areas become inundated (Chakravarti, undated).



The Sundarbans, 100 km downstream from Kolkata

Ecosystem destruction. The eastward expansion of Kolkata due to population growth and influx has been accommodated at the expense of natural ecosystems, mainly the East Kolkata Wetlands. Interestingly, the Basic Development Plan (BDP) for the city, completely disregarding the ecological sensitivity of the EKW, proposes to develop two major townships, namely the Baishnabghata-Patuli Township, and the East Calcutta townships in the EKW. Reclamation of wetlands for garbage dumping also seems to continue unabated (WWF India, 2011).

The Sundarbans, one of most complex and sensitive ecosystem in the world, located 100 km downstream from Kolkata, is severely impacted from the urbanization of Kolkata and the neighboring areas. The Sundarbans, which is part of the delta of the Ganga-Brahmaputra-Meghna basin shared between India and Bangladesh, is home to the largest mangrove forest ecosystems in the world, over 1,400 recorded species, including the iconic Bengal Tiger, *Panthera tigris tigris* and several other threatened species (WWF India, 2011). Hazra (2010) suggests that of the eight rivers that dominate the landscape in India, only the Hooghly and Ichamati-Raimangal carry freshwater flow of some significance. He concludes by stating that the Indian Sundarbans Delta is experiencing both declining freshwater supplies and net erosion as has been recorded since 1969. An equally pronounced ecological change in Sundarbans includes the threat from pollution due to huge discharges of untreated domestic and industrial effluents carried by tributary rivers.

International dispute. Silt deposition in the Hooghly River, a cause for the blockage of the channels supplying water from the river to the EKW, causes additional problems for navigating the Hooghly to the Kolkata port. This, along with water shortages in the dry season and associated increasing tidal salt water intrusion into the river, was planned to be overcome through the construction of the Farraka barrage across the River Ganges some 300 km upstream from Kolkata. The Farraka dam was to divert up to 1,100 m³/s of water from the Ganges into the Hooghly River during the dry season (January - June) to provide a steady flow of water. It diverts over 9% of the Ganges River's historical mean annual flow and over 5% of the flow for the entire Ganges-Brahmaputra basin (Vörösmarty et al., 2005).

About one fourth of the total population of Bangladesh and about one third of India's population live in the Ganges basin. The diversion of up to 60% of the Ganges' water over 25 years has, amongst other things, caused a reduction of water in surface water resources, increased dependence on ground water, destruction of the breeding and raising grounds for 109 species of Gangetic fishes and other aquatic species and amphibians in Bangladesh (Adel, 2001). Since its operation in 1975, there has been ongoing dispute between India and Bangladesh regarding India's diversion of Ganges water, which cuts off a significant portion of Bangladesh's water supply (Salman & Uprety, 2003).

MANAGEMENT MEASURES IMPLEMENTED/SOLUTIONS EXPLORED

Kolkata Environmental Improvement Project (KEIP) is a multi-agency body co-funded by the Asian Development Bank (ADB) to arrest environmental degradation in Kolkata. KEIP's objectives include providing affordable access to basic urban services in slums, revamp and upgrade the sewerage and drainage system, and restore the city's drainage.

User charges for water are recognized by the KMC as the most important mechanism for cost recovery.⁷⁴ One of the major loan covenants of KEIP was the implementation of water metering for every household by 2009/2010⁷⁵, but this has been delayed for political and other reasons.⁷⁶

Rainwater harvesting initiatives for supplementing water supply or aquifer recharge is also encouraged by KMC, but so far, the West Bengal Pollution Control Board has only implemented a few projects.⁷⁷

The East Kolkata Wetlands Management Authority (EKWMA), is constituted by government officials and NGO representatives, and has been entrusted with the responsibility for conservation and maintenance of the East Kolkata Wetlands.⁷⁸ EKWMA has initiated the development of an **integrated management plan**. Inventory and assessments undertaken have stressed the need to adopt an integrated river basin management approach with a shift towards multi-functionality of wetlands. Increasing sedimentation rates, changing quality of sewage from organic to non-organic attributed to industrialisation, sewage allocation between various production systems, changing quality of sewage, addressing poverty, decline in biodiversity and enhancing effectiveness of institutions and governance systems have been identified as the main targets, and specific strategies and action plans were proposed. The authority is also elaborating an ecotourism plan to help realize conservation, as well as, livelihood objectives through sustainable wetland management (Wetlands International, 2010).

WWF INVOLVEMENT

WWF-India has been working in the **Sundarbans** since the launch of Project Tiger in 1973. After functioning through its West Bengal State Office for a number of years, WWF's Sundarbans Program was launched in April 2007 with the mission to stop the degradation of the Sundarbans' natural environment and to build a future in which humans live in harmony with nature. Habitat conservation, adaptation to climate change, advocacy and policy, human-wildlife conflict, livelihood augmentation, capacity building, and research and information dissemination are some of the key areas that the program is working in.⁷⁹





SHANGHAI, CHINA

SHANGHAI, CHINA

GENERAL INFORMATION	
Inhabitants	23,019,148 (2010 Census) ⁸⁰
Population density	3,271.2 persons/km ² ⁸¹
Population growth	3.8% (average population growth 2000-2010) ⁸²
GDP (as estimated in 2008, \$bn at PPP)	US\$ 233 billion (rank 25) (Hawksworth et al., 2009)
Contribution to national GDP	4.2% (Census 2010)
Area	7,037 km ² ⁸³
Climate	Northern subtropical maritime monsoon climate characterized by mild annual temperatures, high humidity, and distinct seasons ⁸⁴
Altitude	4 m
Mean temperature	15.8°C
Mean annual rainfall	1,112 mm ⁸⁵
WATER STATISTICS	
DOMESTIC water use (liter per capita)	411.1 l/capita (Economist Intelligence Unit, 2011)
% households with water access	~100% ⁸⁶
% water loss due to leakage in pipe systems	10.2% (Economist Intelligence Unit, 2011)
Water price for domestic households	1.63 Yuan/m ³ (US 0.2587) ⁸⁸
% households with sewerage services	73% (Economist Intelligence Unit, 2011)
% wastewater treated	78% (Economist Intelligence Unit, 2011)
Main water sources	Huangpu River Yangtze River
Main water problems	Pollution in the Huangpu River Saltwater intrusion in the Yangtze estuary



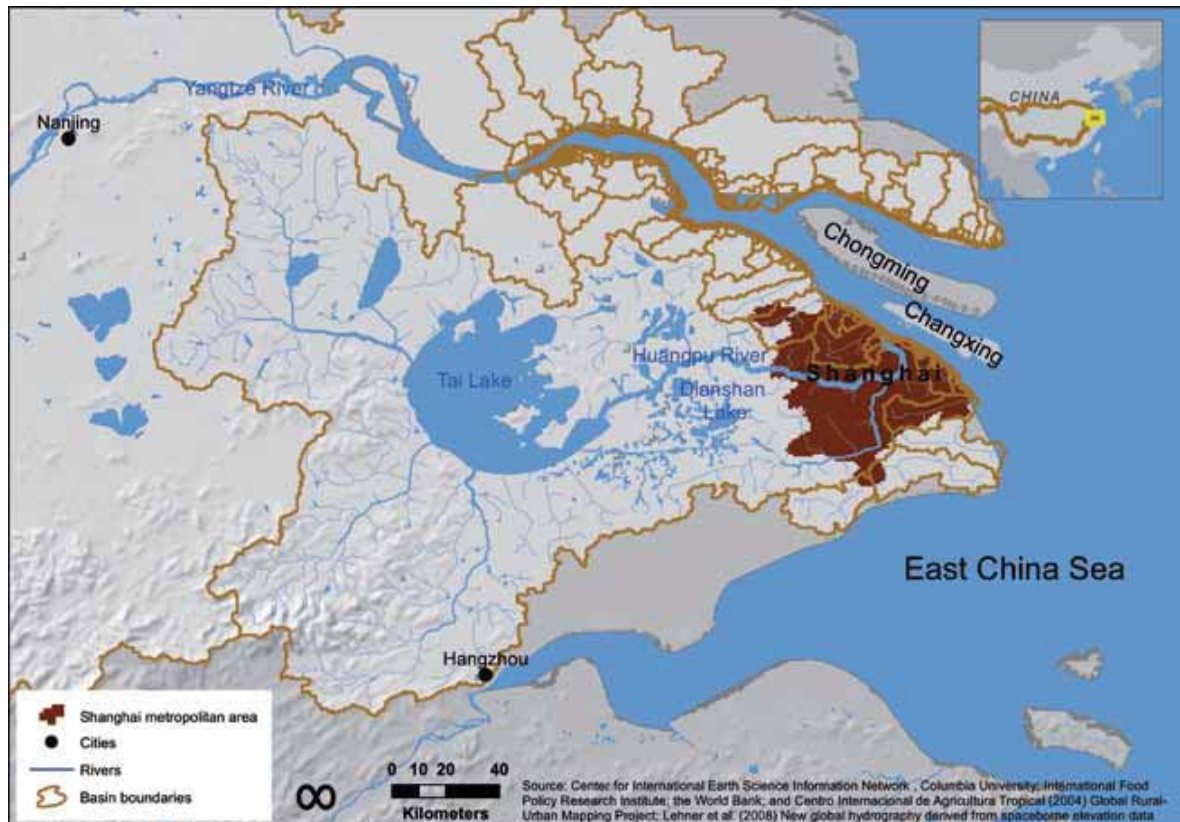
Nanjing Road, Shanghai

In the 11th century, Shanghai evolved from a small fishing village to a town; it gained economic and international importance in the 19th century. In the 1980s, the city's economy began to boom, and Shanghai became one of the world's 10 largest megacities. Today, the metropolitan area has more than 23 million inhabitants and the city's GDP (estimated at PPP) ranks 25th worldwide (Hawksworth et al., 2008). The growth of both the economy and population is not predicted to slow down significantly in the coming years.

CATCHMENT AREA

The Huangpu River and Yangtze River serve as surface water sources for Shanghai's water supply. The Huangpu River is about 114 km long, originates from Tai Lake and Dianshan Lake in the west of Shanghai, bisects the city and terminates in the Yangtze estuary. It drains an area of 5,193 km², covering 80% of Shanghai. As 83 km flow through Shanghai's urban area, the Huangpu River is heavily affected by domestic, industrial, and agricultural pollution (Zhang, 2007). The upper reaches of the Huangpu River run through suburban Shanghai, characterized by intensive agriculture activities and animal breeding operations, while its lower reaches flow through urban areas with intensive industrial activities and residential areas (Jiang et al., 2011). The Shanghai municipality is 11% water (Ge, 1998).

The Yangtze River is the longest river in Asia (6,418 km). It originates from the Tibetan plateau and drains into the East China Sea. The Yangtze River Basin is home to one third of China's population and flows through 19 provinces, autonomous regions, and municipalities. It contributes both grain and GDP, accounting for one third of the nation's totals.⁸⁹



DRINKING WATER

The city mainly relies on surface water derived from three major sites along the Yangtze estuary and the Huangpu River. Whereas the city strongly depended on water from the Huangpu River in the past, there is a shift towards the Yangtze River. Water supply from protected areas plays a minor role in Shanghai (Dudley & Stolton, 2003), although there are some promising small scale pilot projects to show how water quality increases after flowing through protected river and lake catchment areas (see the end of this chapter). To a certain extent, groundwater aquifers are protected by law - the use of groundwater is prohibited whenever surface water is available (Regulations of Shanghai Municipality on the Administration of Water Supply, article 12).⁹⁰ Deep-water wells are of less importance as suburban and rural households in Shanghai municipality gain increasing access to piped water (Ren et al., 2003).

Water reservoirs

1. Yangtze River / Qingcaosha reservoir: Shanghai's main site for abstraction of water from the Yangtze River is the 70 km² Qingcaosha reservoir (total reservoir capacity of 524 m³, effective capacity of 435 million m³, daily water supply of 7.19 million m³). It is located north of Changxing Island in the Yangtze River estuary and designed to secure 68 days of Shanghai's water supply without refilling from the Yangtze River. Qingcaosha reservoir went into operation in December 2010 and currently provides about 50 % of Shanghai's water. In 2012, Shanghai plans to derive 70 % of its water from the newly opened reservoir in the Yangtze River.⁹¹

2. Yangtze River / Chenhang reservoir: The second site for water abstraction from the Yangtze River is located at the mouth of the river and has a capacity of 9.5 million m³. Until 2010, Chenhang reservoir provided one third of Shanghai's total water supply and was the sole water source for more than 3 million people in northern Shanghai. It is claimed that the reservoir could secure water supply for seven days without refilling.⁹²

3. Huangpu River / upper reaches: The former main water source of metropolitan Shanghai is located near the upper reaches of the Huangpu River. It accounted for about 70-80 % of Shanghai's total water supply until Qingcaosha reservoir was opened.⁹³

Compared to other megacities in the world, Shanghai's water infrastructure is very modern. Almost 100 % of residents have access to water and only up to 10 % of water is lost due to leakages in the pipe system (Economist Intelligence Unit, 2011). Shanghai's daily water yield was 609 million m³ in July 2010.⁹⁴

WASTEWATER TREATMENT

According to the Asian Green City Index, 78 % of Shanghai's wastewater is treated. 73 % of households have access to sewerage service (Economist Intelligence Unit, 2011). The Shanghai municipal government plans to raise the wastewater treatment ratio to 90 % by 2020, with wastewater collection and treatment covering the whole of downtown Shanghai. These steps are meant to ease the extent of pollution of the river systems around Shanghai (Fu et al., 2008; ADB, 2010). A wastewater treatment fee of 1.30 Yuan (US\$ 0.20) per cubic meter is currently built into the water tariff in Shanghai. Wastewater and drainage services fall under the Shanghai Sewerage Company.⁹⁵



The Yangtze River

WATER GOVERNANCE & MANAGEMENT

Shanghai Water Authority (SWA) is mainly responsible for water management. There is a comprehensive set of national and local laws and standards for water quality, utilization, discharge and monitoring in place.⁹⁶ The main legislative framework for Shanghai (“Regulations of Shanghai Municipality on the Administration of Water Supply”) was adopted in June 1996 and underwent two revisions in 2003 and 2006. Shanghai has established four water companies and several research institutes (Shanghai Water Supply Planning Design and Research Institute etc.) and stations to monitor water quality. Shanghai Water Authority is reported to have a budget of 4.6 billion Yuan (US\$ 0.72 billion), which is 6 % of Shanghai’s total city budget.⁹⁷

Shanghai’s water tariffs range from 1.63 Yuan per m³ (US\$ 0.25) for domestic households to higher prices for special industries (for example, car washes pay 5.60 Yuan per m³ (US\$ 0.9) and saunas pay 15.6 Yuan per m³ (US\$ 2.43)).⁹⁸ With an average monthly wage of 3,896 Yuan in 2010⁹⁹, one cubic meter equals 0.03 % of a worker’s average income in Shanghai. The price for domestic water was raised by 23 % in November 2010.

MAIN WATER ISSUES

Although freshwater is naturally abundant in Shanghai metropolitan area, the city experiences high water stress (Li et al., 2010a). Rising demand, pollution, and saltwater intrusion are challenging the existing water reservoirs and threatening the city’s water security. All main problems are aggravated by climate change.

Pollution. Intensive long-term research has identified a number of water quality challenges confronting Shanghai. The development of modern and intensive agricultural practices brought fertilizers and insecticides into the urban environment. Residues from these chemicals flow into the river during rainfall events, causing river eutrophication among other impacts (Kung Hsiang et al., 1991). Low capacity of sewage treatment has resulted in industrial and residential waste being discharged directly into the city’s watershed (Ward et al., 1995). Pollution sources have gradually changed from point sources to non-point sources, which include fertilizer, insecticides, domestic animal waste from agricultural activities, and wastewater from villages and town-owned factories (Ren et al., 2003). Although metal pollution has been efficiently restricted in recent years, non-point organic pollution has increased as human sewage increases in the Huangpu River (Zhang et al., 2007). Wastewater, as well as industrial and agricultural pollution, has led to blue-green algae outbreak in Tai Lake and in the Yangtze estuary in warm weather conditions.¹⁰⁰ With changes in living standards and consumption patterns, new sources of pollution, like pharmaceutical products in residential wastewater, might cause additional problems in the future and are the subject of recent studies (Jiang et al., 2011). The rating of drinking water in the box below indicates that pollution and the resulting treatment costs are causing major challenges for Shanghai’s water security.

Drinking water standards

China's Environmental Quality Standards for Surface Water describes water quality in six grades. Grade I-III are possible drinking water sources, grade IV and V are safe for general industrial and agricultural use respectively, grade V minus is considered water unsafe for any use. Shanghai's drinking water officially rated as II-V in 2008, making it partially unsafe for drinking. Due to organic pollution, Shanghai's Huangpu River is in worse condition than the Yangtze River in the estuary area. In 2008, the water quality for the Yangtze River mouth, the upper reaches of Huangpu river, and the main streams of Chongming Island in the Yangtze River delta ranged from grade II to grade IV. The municipal inland river network was evaluated unsafe for drinking (IV-V). According to the Shanghai Hydrological Station (Water Environmental Monitoring Center), the organic pollution indices ranged from II-V minus.¹⁰¹

Salt water intrusion. Saltwater intrusion is a phenomenon that naturally occurs in the Yangtze estuary during the dry season in winter and early spring when seawater backs into the Yangtze River and mixes with the freshwater, thereby making it unsafe to drink.¹⁰² According to news releases, saltwater intrusion has become increasingly serious in recent years, and salinity is now a major threat to Shanghai's water security. As a result of a severe drought along the middle and lower reaches of the Yangtze River in 2011, salt water tides persisted until early summer with salt water intrusions in April (9 days), May, and June, a situation that has not occurred in the last decade.¹⁰³

Several research projects show that the change of salinity in the Yangtze River mouth is mostly affected by (1) river discharge, (2) astronomical tide, (3) typhoon and other extreme weather events. The Yangtze's discharge is the most important factor, but extreme situations will happen when three factors occur at one given moment. Saltwater intrusion regularly occurs in the dry season, a time when the discharge of the Yangtze is low. Severe draughts, but also infrastructure projects have the potential to reduce river discharge and prolong the period of salt tides (Zheng et al., 2011).

Influence of major hydraulic projects. The Three Gorges Project (TGP), the South-to-North Water Diversion Project (SNWDP), water diversion from the Yangtze to Lake Tai basin, and other water diversions from the Yangtze River influence river discharge in the Yangtze estuary area (Pittock et al., 2009). Studies forecast that the SNWDP's maximum water diversion scheme of SNWDP will aggravate saltwater intrusion as this will cover one-tenth water discharge during the low-level season while the increased discharge of TGP during the dry season can restrain saltwater intrusion in the estuary (Zheng et al., 2011).

Climate change. Due to the city's low elevation and proximity to the Yangtze estuary, Shanghai is highly vulnerable to climate change. A rising sea level might aggravate salt-water intrusion and extreme weather events, such as storms, floods, and droughts, will further endanger the city's water supply. As healthy ecosystems are most resilient to climate change, protection of the catchment areas (Yangtze River and Huangpu River) and PES schemes to compensate upstream communities for protective measures will become increasingly important.

Water Footprint of Consumption In 2007, no other Chinese region had a higher per capita water footprint of consumption than Shanghai municipality. The average per capita water footprint of consumption (also: indirect water footprint) in Shanghai was about 1,000 m³ per year; China's average per capita Water Footprint was 679 m³ per year in comparison, or 43 % of the global average of 1,564 m³ per year in 2004 (Chapagain & Orr, 2008).

In Shanghai, the blue water (surface and groundwater) footprint exceeded the green (rainwater) and the grey water (polluted water) footprint by far. Two thirds of Shanghai's water footprint accounted for blue water, about 25 % for grey water and less than 10 % for green water. The blue water footprint in other Chinese regions did not exceed 30 % except for in the desert area of Xinjiang.

Shanghai municipality's internal water footprint (the volume of domestic water resources used to produce the goods consumed in that region) is larger than the external water footprint, but very low in comparison with other Chinese regions. Main factors influencing the water footprint of consumption in China include high levels of economic development, changes in lifestyle, and agricultural water use patterns. (source: Li et al., 2010: WWF China Ecological Footprint Report 2010)



Construction of the Three Gorges dam on the Yangtze River

MANAGEMENT MEASURES IMPLEMENTED/ SOLUTIONS EXPLORED¹⁰⁴

Infrastructure measures/opening new water sources. To meet rising demand, rely less on polluted water from the Huangpu River, and decrease the threat of salinity, Shanghai built the Qingcaosha reservoir. The Reservoir is located in an area where salinity is the lowest in the estuary and now provides 50 % of Shanghai's daily water supply, which will increase to 70 % in the coming year. It was designed to provide Shanghai with water for 68 days, which reflects the theoretical extreme salt water intrusion situation Shanghai may have to face.¹⁰⁵ However, 68 days might be insufficient as blue algae, eutrophication, and other problems could further reduce its available capacity.

Increasing consumption tariffs. In 2010, authorities raised the tariff for domestic water by 23 %³. Ma Jun, director of the Institute of Public and Environmental Affairs, advocates raising water prices to promote conservation, but said seawater purification would not be seen as an ideal choice as it consumes large amounts of energy.¹⁰⁶

Water source protection. A 2008 WWF demonstration project in the upper reaches of the Huangpu River shows how the restoration of rural wetland ecosystems can improve water quality (see text box).

WWF–HSBC Demonstration Project of Water Source Protection – Wetland Restoration in Dalian Lake

“Lake Dalian Model” (42 hectares demonstration area), launched November 2008 Lake Dalian is located in the lower reaches of Dianshan Lake, whose water flows into the Huangpu River’s water intake. Dalian Lake is important because it purifies the water from Dianshan Lake, which controls the non-point pollution in the countryside and improves the water quality in the water source region of the Huangpu River. The aim of “Lake Dalian Model” is to restore healthy wetland ecosystems in the rural water source area to ensure that quality water reaches metropolitan Shanghai.

Project measures: modification of the topography and restoration of wetland ecosystem using advanced wetland restoration techniques; eco-agriculture; 10 hectares forest conservation.

Project partners: People’s Government of Qingpu district, Shanghai Landscape and City Appearance Administrative Bureau, Nanjing University

Results: Improvement of water quality from Grade V and worse to Grade II-III, meeting drinking water standards (aquatic plants remove 83 tons of suspended particles, 2300 kg of nitrogen and 290 kg of phosphorus per year); increased biodiversity; considerable economic value produced by wetland products of 84,000 Yuan (about US\$13,000) of annual net income from 0.5 hectares of wetland restoration area by harvesting crops like wild rice grass, cress, lotus, and ecologically cultured fish.
(source: WWF China 2009)

Flooding in East Dongting Lake, Yuyang City, Hunan Province, China

WWF China is also involved in the protection of China’s two largest freshwater lakes - the Dongting and Poyang Lake, which are connected to the Yangtze River in its middle reaches. Improving the lakes’ water quality is not only beneficial for local communities and key species (like the Yangtze finless porpoise and thousands of migratory birds), but also improves the water quality of downstream drinking reservoirs, like in Shanghai at the Yangtze estuary. When concerning a city’s water supply, it is important to look beyond the immediate vicinity.



ALTERNATIVE SUSTAINABLE APPROACHES?

Shanghai has many rivers and creeks, but most of them are polluted and many are isolated from external flowing water systems. If the natural water system in urban Shanghai can be restored more naturally and effectively, it will not only benefit the city's landscape and estuary biodiversity, but also improve water quality of ground and surface water and increase resilience to extreme rainfall.

Coastal wetlands, which provide a natural buffer zone against climate change impacts, such as sea level rise and storms, have to be protected. So far, people rely more on dikes. WWF is working with partners to protect the coastal wetlands, not only for migratory birds and aquatic biodiversity, but also to safeguard the city. The large area of coastal wetland is also a good purification means for the inland water.¹⁰⁷

As Shanghai will derive up to 70 % of its drinking water from the Yangtze River, the Payment for Environmental Services (PES) scheme can play an important role in the city's future water security. A possible platform for PES is the Yangtze Forum. During the Third Yangtze Forum in 2009, the Yangtze Declaration on Yangtze Estuary Protection and Management called for increased efforts to balance resource protection and economic development with more effective regional coordination, improved wastewater treatment, and more comprehensive use of PES.¹⁰⁸ Shanghai's water footprint, with the lowest ratio of green water (rainwater) footprint compared to other Chinese regions (Li et al., 2010a), provides a basis for discussions on how to make better use of green water in Shanghai's footprint context.

*The Tiger Leaping Gorge
near Lijiang downstream
from Shigu*



CHAPTER 4: CONCLUSIONS

Urbanization is not per se bad for ecosystems. Many ecosystems in and around urban areas deliver more environmental services than agricultural systems. They provide food, water services, comfort, amenities, and cultural values, particularly if well managed. Moreover, urban areas only occupy about 2.8 % of Earth's total land area (Mc Granahan et al., 2005); thereby, greatly concentrating the area impacted by human settlements.

However, for cities to be sustainable, reliable access to safe drinking water and adequate sanitation are important prerequisites (UNEP, 2011). The adoption and implementation of ecosystem-based approaches is vital for improving the future condition of water-provisioning services by balancing economic development, ecosystem conservation, and human well-being objectives (Vörösmarty et al., 2005).

Sustainability goes beyond physical engineering and manipulation of water flows. Large-scale technological approaches to ensuring water supply, such as dams and inter-basin transfers, have doubtlessly been beneficial, providing stable water flows and electricity to certain regions. However, they have also created unforeseeable problems, such as water scarcity in areas where water flows have been diverted from and impacts on biodiversity through habitat fragmentation or loss of sediments (Vörösmarty et al., 2005). Before considering further technical manipulations and alterations of water flows, it is generally acknowledged that management approaches should form a larger proportion of proposed solutions. Moving away from a focus of satisfying growing demand to also managing demand itself is a key concept in modern water management.

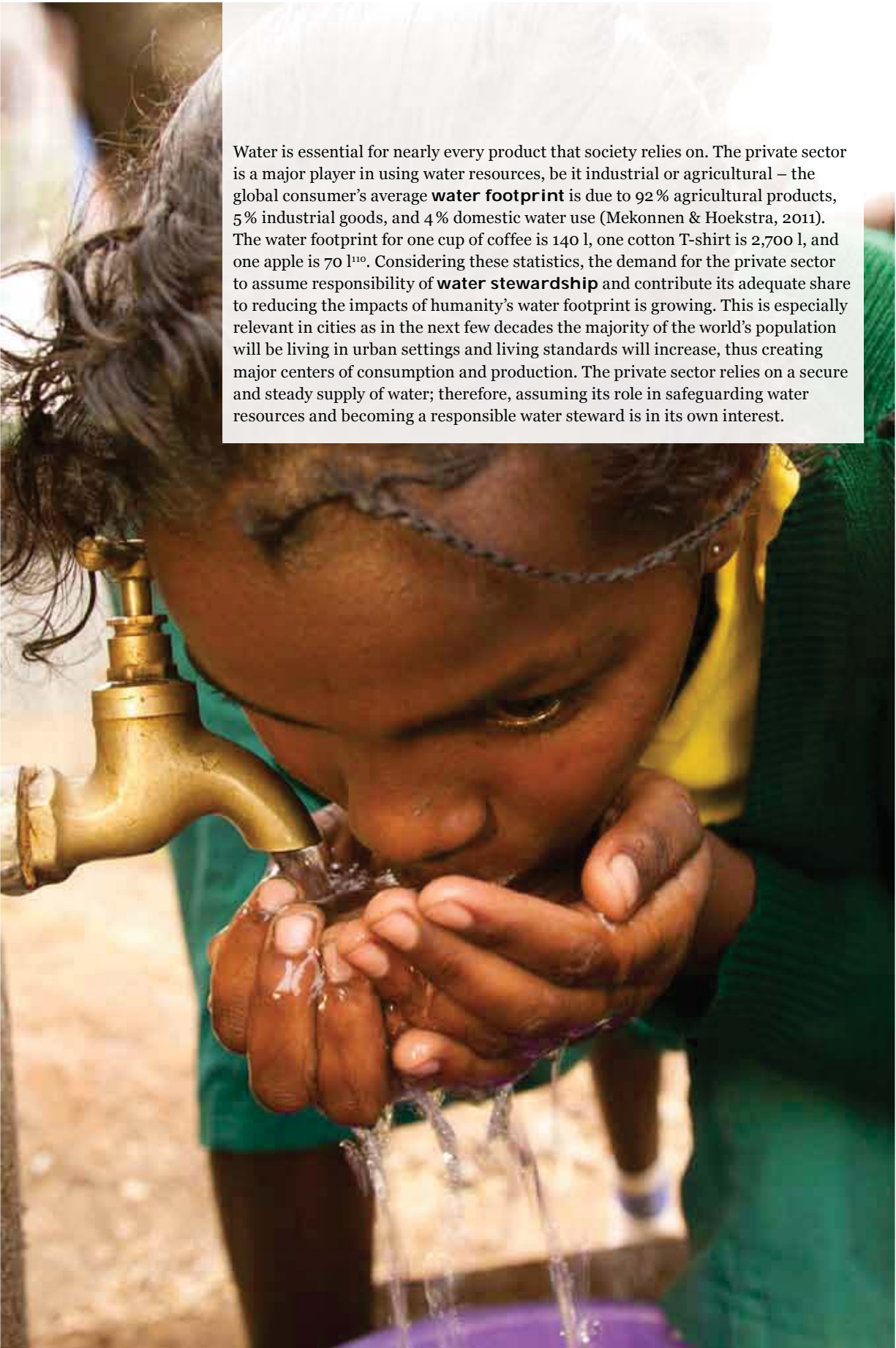
WATER MANAGEMENT APPROACHES

Cities are hotspots of consumption- and by this token; they have amazing potential for reducing their water footprint. “Simple” instruments for **demand reduction**, such as appropriate pricing, techniques like rainwater harvesting or wastewater recycling can have major impacts when implemented and enforced widely on households and industry. Involving marginalized groups into management solutions and implementation is crucial, as the success of Karachi’s Orangi Pilot Project clearly demonstrates. Creating a sense of ownership for infrastructure and service provisions also ensures sustainability in their maintenance.

Raising awareness for the sustainable and efficient use of water resources amongst the general public, and especially in agriculture and industry, is essential. Community, industry, and school education programs can raise awareness about the need to conserve water and to bring about long-term changes in water consumption behavior. It must be assured that the targeted community, authority, commercial entity, or any other stakeholder can obtain the necessary information and understand water management practices available for their own needs and local circumstances (Pitcock et al., 2009).

Rainwater harvesting has been used extensively to directly recharge groundwater at rates exceeding natural recharge conditions in India. Reports from international organizations focusing on this area indicate that 11 recent projects across Delhi resulted in groundwater level increases from 5 to 10 metres in just two years. In fact, the application of rainwater management in India is likely to become one of the most modern in the world (Pitcock et al., 2009). Rainwater harvesting is practiced on a large scale in Chennai, Bangalore and Delhi where it is included in the state policy and in the building code for new buildings¹⁰⁹. Collecting rainwater from the abundant rainfalls during the monsoon season is also a feasible option for cities like Karachi and Kolkata.

Treatment and reuse of water from storm water drainage, sewage and other effluents, and industry can greatly supplement local water supplies. Annual reclaimed water volumes total about 2.2 billion m³, based on 2000 and 2001 figures from the World Bank (WWAP, 2006). On a global scale, non-potable water reuse is currently the dominant method for supplementing supplies for irrigation, industrial cooling, and river flows (Pitcock et al., 2009). For industry, wastewater recycling and reuse can be encouraged through fiscal incentives (subsidies) and pollution taxes (Bhatia & Falkenmark, 1992). Recovered water or stormwater can also be used to directly recharge groundwater aquifers and thus also create a barrier to saltwater intrusion (Pitcock et al., 2009). Wastewater recycling has been used to recharge Mexico’s City overexploited aquifers and halt the City’s subsidence since 1992 (environmental norms were implemented to regulate the water quality in 2007) (Sosa-Rodriguez, 2010). Recycled wastewater in metropolitan Mexico City is also used to irrigate green areas, fill lakes and canals, and cool industrial processes.



Water is essential for nearly every product that society relies on. The private sector is a major player in using water resources, be it industrial or agricultural – the global consumer’s average **water footprint** is due to 92 % agricultural products, 5 % industrial goods, and 4 % domestic water use (Mekonnen & Hoekstra, 2011). The water footprint for one cup of coffee is 140 l, one cotton T-shirt is 2,700 l, and one apple is 70 l¹⁰⁰. Considering these statistics, the demand for the private sector to assume responsibility of **water stewardship** and contribute its adequate share to reducing the impacts of humanity’s water footprint is growing. This is especially relevant in cities as in the next few decades the majority of the world’s population will be living in urban settings and living standards will increase, thus creating major centers of consumption and production. The private sector relies on a secure and steady supply of water; therefore, assuming its role in safeguarding water resources and becoming a responsible water steward is in its own interest.

Economic and fiscal incentives and instruments are another possible option to aid the reduction in water demand, effective water basin management by upstream farmers and landowners, or reducing water pollution by industrial users. Water is still perceived as an abundant and free resource and not as an economic good. Due to heavy subsidization, **water prices** are usually so low that they reflect neither the true economic value nor the costs needed for water provision (infrastructure, treatment, maintenance). In addition, many countries do not meter consumption and users pay a fixed rate regardless of how much they actually consume. Without adequate price signals, there is no incentive for using water more efficiently or for reducing water consumption. There is evidence from both developed and developing countries that a mix of regulatory and economic/fiscal incentives have led to 20-30 % reductions in industrial and household water use in the past (Bhatia & Falkenmark, 1992).

Cost recovery for the institutions governing water provision is a major problem in most cities, as illustrated by the examples of all of the cities analyzed in this report. Incorporating infrastructure maintenance, provision and administrative costs into the water price would lead to better cost recovery, and thus generate needed resources for infrastructure improvements and other water management solutions. Additionally, it would also lead users to economize. An essential component of Buenos Aires' water management plan is the installation of water usage meters across the city. In 2009, only 12.8 % of water users had their consumption metered, thereby encouraging the highest per capita water consumption in this report. Through increasing metered connections by 600 % (from the current 3,000 to 18,000) from 2009 - 2012, it is estimated that 100,000 m³ of water will be saved daily (Garzon et al., 2009). Mexico City reported water conservation after installing meters for 90 % of its users in 1994 (Tortajada, 2006). Installation of meters is also planned for Nairobi's informal settlements.

Integrated River Basin Management (IRBM) is one of the 21st century's biggest challenges, but at the same time, it offers a great opportunity for sustainable water resource management in river basins. It refers to a management system where economic, environmental, social administration, and governance is integrated across administrative and regional boundaries. This cross-sectoral approach stems from the recognition that various and competing stakeholders have their own interest in managing water resources. It is increasingly acknowledged that management must become transparent between stakeholders and there has to be communication between administrations and governments regulating water use across the entire river basin. Only in this way, can economic and social benefits derived from water resources be maximized in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems¹¹¹. Mexico administers its water by regional watershed bodies with basin organizations serving as the "technical arm" of broad-based basin councils, incorporating civil society interests (private sector, citizens' groups, etc) (Scott & Banister, 2008). China's platform for Integrated River Basin Management is the Yangtze Forum, which aims to sustainably manage and develop the Yangtze River. The initiative was launched by authorities of the central government and all relevant provinces, autonomous regions, and municipalities along the Yangtze mainstream and incorporates all stakeholders, as well as domestic and international organizations.¹¹²

Payment for Environmental Services (PES) is a market-based tool that can be integrated into the IRBM approach as a way to create financial incentives for managing natural resources, addressing livelihood issues for the rural poor, and providing sustainable financing for protected areas. The basic principle is that those who “provide” environmental services by conserving natural ecosystems should be compensated by beneficiaries of the service (WWF, 2006). In the case of freshwater, upstream landowners that protect the watershed (foregoing more lucrative uses of their land, such as agriculture, and incurring costs for implementing conservation measures) are providing a service to downstream users (cities, agriculture, hydropower companies, beverage industry, etc.). Maintaining land in its natural state or implementing conservation techniques and thereby providing environmental services is seldom a more attractive option than its conversion because beneficiaries are not the service provider (the land owner). PES aims to change this by providing incentives for maintaining or restoring land for the desired environmental service (Pittock et al., 2009).

A PES scheme for watershed protection was successfully implemented in the Naivasha Basin in Kenya. It could serve as a model for cities around the world. In Kenya, the Naivasha PES scheme is the first of its kind; the success of the program has generated enormous interest from various government authorities, institutions, and local communities.

Payment for Environmental Services – A Solution to clean water supply for cities

In Kenya’s Lake Naivasha basin, World Wide Fund for Nature (WWF-Kenya Country office) in partnership with CARE-Kenya is piloting a PES scheme where downstream communities reward land-owners upstream who voluntarily undertake conservation measures that reduce silt load in rivers and consequently ensure the availability of clean water.

Conservation efforts include rehabilitation and maintenance of riparian zones, establishment of grass strips and terracing along steep slopes, reduction of agro-chemical use, and planting native trees and high yielding fruit trees and cover crops for improved farm productivity – all of which is expected to result in improved freshwater quality and quantity, in addition to improving livelihoods.

Sellers and Buyers: This scheme involves 565 upstream small-scale farmers as the sellers of Environmental Services (ES) to the downstream Lake Naivasha Growers Group (LNGG), which includes 23 commercial floriculture/horticulture farms.

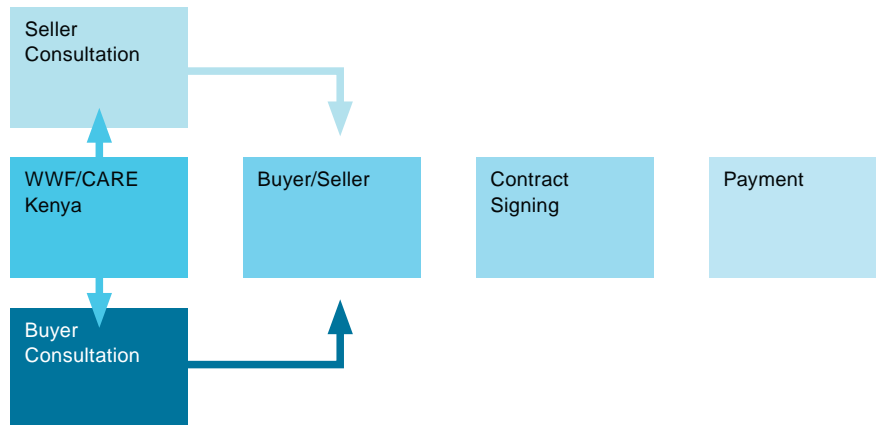
Management: The scheme is administered through a legal contract between the Water Resource Users (WRUAs) that represents both buyers and sellers.

The objective of the Naivasha PES scheme is to develop a viable mechanism of PES (in this case for good water quality) that sustainably manages natural resources while also improving rural livelihoods.

Project set-up – a three-phased approach

1) Feasibility assessment; 2) Establish pilot PES that engages a few communities within a sub-catchment upstream and a few major water users downstream; and 3) Scale-up scheme to deliver ecosystem service improvements that buyers ultimately require with the buyers assuming a much larger share of the cost. The upstream WRUAs manage the scheme on behalf of the implementing land-owners (sellers), while Lake Naivasha Water Resource Users Association (LANAWRUA) represents the buyers downstream. The scheme's pilots sites were selected based on a hydrological assessment, business case analysis, impact assessment on livelihood improvement, and legal framework, community (buyers/sellers) mobilization, selection of target farms, mapping and laying out of conservation structures, and buyer-seller agreement. Disbursement of incentives is based on field and hydrological monitoring.

PES scheme buyer-seller negotiation process



Water Resources Director, Mr John Nyaoro (L) receives check from LANAWRUA chairman Mr. Richard Fox (R) before handing over to Upper Turasha WRUA members behind

What are PES multiple benefits? The PES scheme benefits nature and people within Lake Naivasha Basin. Soil fertility has improved as seen through increased farm productivity and soil erosion has decreased through the grass strips combined with terracing. Erosion control is reducing silt load in rivers, which benefits biodiversity and ensures clean water for downstream users. Farmers have enough fodder for their livestock, thereby increasing milk yield and reducing pressure on forests from grazing. High quality fruit trees and potatoes provide nutrition and income to farmers.

Results

- » Land use changes implemented in all participating sites
- » Buyers and sellers signed two contracts
- » Incentives: 2 WRUAs rewarded US\$ 10,000 as first incentive and US\$ 8,546 as second incentive
- » 32 farmers trained as para-professionals on soil & water conservation, farming techniques and good agricultural practice - laid out additional 170 new farms for conservation



Farmer admires his Napier grass strip that he will use as fodder for his livestock

Challenges

- » No capacity currently to address the high demand from other farmers to join PES scheme
- » Unpredictable weather pattern
- » Degraded public lands
- » Complex land ownership
- » Low buy-in from buyers

Lessons learnt

- » Sustainable provision of Ecosystem Services (ES) is achieved through sustainable land-use practice changes & equitable incentives to farmers that addresses livelihoods
- » Strong stakeholder partnership leads to successful PES implementation
- » Necessary preconditions: initial baseline to identify hydrology problem, establish strong business case, build trust, commitment, ability to sell, and pay for ES to ensure long-term sustainability and ownership of PES scheme
- » Appropriate and adequate capacity building of ES providers and beneficiaries strengthen skills in implementing the PES scheme

(source WWF Kenya)

Climate change adaptation requires flexibility insofar that water management systems have redundancies, institutions are capable of monitoring important ecosystem and social indicator variables, institutions learn and adjust their policies in response to new information, and decision-making is decentralized and coordinated (Matthews & Quesne, 2009). There are eight elements to freshwater climate adaptation outlined in WWF's Water Security Report: develop institutional capacity, create flexible allocation systems and agreements, reduce external non-climate pressures, help human communities and economies move ranges, consider water infrastructure development and management carefully, institute sustainable flood management policies, support climate-aware government and development planning, and improve monitoring and response capacity (Matthews & Quesne, 2009).

CHAPTER 5: RECOMMENDATIONS FOR SHORT TERM, IMMEDIATE ACTIONS AND LONGER TERM STRATEGIES

For sustainable water management, it is key that cities **protect and restore ecosystems** that are important water sources. This will provide cheaper, more efficient, and flood resilient water supply systems for the world's increasingly urban areas. Protecting critical habitat provides multiple benefits by providing natural

buffers for human infrastructure and important refuges for plants and animals that may otherwise be at risk from the diverse effects human society can have on these ecosystems, including climate change.


Cities need to reduce water consumption, recycle wastewater, restore adjacent watersheds, and improve engineering solutions to supply water from well-managed ecosystems. The adoption of a **multi-sectoral approach** to water and wastewater management at the national level is a matter of urgency. This approach should be implemented by incorporating principles of **ecosystem-based management** extending from the watersheds to the sea, and connecting sectors that will reap immediate benefits from better water and wastewater management. Ecosystem protection, management, and restoration provide a central, effective, sustainable, and economically viable solution to enhancing water supply and quality while mitigating extreme weather events of too much or too little water.

Luiz Firmino M. Pereira with water quality testing equipment at outfall pipe in Ararauama. Part of one of the WWF Freshwater projects sponsored by HSBC. Rio de Janeiro State, Brazil



Successful and **sustainable wastewater management** that supports peri-urban agriculture is crucial for reducing water consumption, and requires a mix of innovative approaches that engage the public and private sector at local, national, and trans-boundary scales. Planning processes should provide an enabling multi-scale environment for innovation, including at the community level with government oversight and public management.

For cities to better understand their vulnerabilities as well as prepare for the impacts of climate change, they must examine the full suite of potential impacts, both at a regional and local level. **Vulnerability and water risk assessments** covering the core urban and peri-urban areas, as well as areas that supply water and goods and services that include a complete evaluation of water-related risks such as future water availability, precipitation, drought, runoff patterns, sea level rise, and flooding risks are needed. Local plans should be strengthened by encouraging and, where possible, requiring water and energy utility operators to prepare and update their own site- and system-specific vulnerability assessments that should address utility vulnerability to flooding, drought, and/or sea level rise. More informed political and financial decisions can be made with access to more diverse information about risks and probabilities. By considering a range of risks, local efforts provide better opportunity for effective long-term adjustment and management.



Local involvement is key to any vulnerability assessment and adaptation strategy. Proper planning should include not only city personnel, but also representatives from local water and energy utilities, emergency response personnel, natural resource managers, homeowners, businesses, and environmental groups. The businesses, farmers, and food processors (i.e. the supply chain structure) for the city's agricultural and food products, as well as, the city's downstream water users should participate equally in the formulation of adaptation strategies and their implementation.

Innovative financing of water and wastewater infrastructure should incorporate design, construction, operation, maintenance, upgrading and/or decommissioning. Financing should take the important livelihood opportunities in improving wastewater treatment processes into account, while the private sector can play an important role in operational efficiency under appropriate public guidance, including ecosystem restoration projects.

An **inventory of critical infrastructure** that is at risk due to flooding, droughts, or sea level rise is also fundamental. So as to inform longer-term planning, construction, funding, and other resiliency goals, the identification of critical facilities at risk (such as roads, hospitals, drinking water supplies and conveyance systems, sewage treatment and conveyance infrastructure) should be prioritized in the short term. Identifying this critical infrastructure should be based on available information and refined as improved data becomes available.

The use of **green infrastructure and low-impact development** in watershed planning offers many benefits and should be encouraged in local planning. Large volumes of storm-water runoff that is discharged through municipal sewer systems can exacerbate storm surges and cause flooding in urban settings. Green infrastructure can capture the runoff, thereby both augmenting water supply and reducing downstream flooding. Low-impact development is a simple and cost-effective green development strategy that can help cities, states, and even individuals meet the water supply challenge. In areas where the groundwater table is too high for infiltration, practices that evaporate or evapotranspire water, like rain gardens or capture-and-use systems (rain barrels and cisterns) can be successfully used. Broad introduction of urban and peri-urban agriculture utilizes otherwise wasted runoff and decreases the reliance on surrounding rural regions for food crops, consequently easing the city's external indirect water footprint impact.

Increasing energy efficiency reduces current and future demand for energy, decreases water consumption related to energy production, and reduces greenhouse gas emissions. Cities should take steps to implement comprehensive and ambitious programs for energy efficiency and saving that promote clean and water-efficient forms of energy such as wind, solar, and geothermal.

Solutions for smart water and waste management must be socially and culturally appropriate and acceptable, as well as economically and environmentally viable. Ecosystem protection, management, and restoration are the cheapest, easiest, and most effective ways of improving and securing water supply, filtration, and quality. Education must play a central role in water management and in reducing city's unsustainable demand on water resources.

Intensive cultivation of Soybeans etc. using rotary irrigation system, near Brasília.

References

CHAPTER 1: INTRODUCTION

Dudley, N., Stolton, S. (2003). *Running Pure: The importance of forest protected areas to drinking water*. World Bank/WWF Alliance for Forest Conservation and Sustainable Use

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M. (2011). *The Water Footprint Assessment Manual – Setting the Global Standard*. Water Footprint Network

IPCC (2008). *Climate Change and Water*. IPCC Technical Paper VI. IPCC Working Group II. Technical Support Unit. Intergovernmental Panel on Climate Change

Leach, M., Mearns, R. (eds) (1996). *The Lie of the Land: Challenging Received Wisdom on the African Environment*. International African Institute in association with James Currey

Li, L., Xie G.D., Cao S.Y., Luo Z.H., Humphrey, S., Cheng, S.K., Gai L.Q., Li H.Y., Ewing, B. (2010). *China Ecological Footprint - Biocapacity, cities and development*. WWF China

Matthews, J., Quesne, T. (2009). *Adapting Water Management - A primer on coping with climate change*. WWF Water Security Series 3. WWF - UK

McGranahan, G., Marcotullio, P. Bai, X., Balk, D., Braga, T., Douglas, I., Elmqvist, T., Rees, W., Satterthwaite, D., Songsore, J., Zlotnik, H., Eades, J., Ezcurra, E. (2005). Chapter 27, *Urban Systems*. In: R. Hassan, R. Scholes, N. Ash (eds.): *Ecosystems and Human Well-being: Current State and Trends, Volume 1. Millennium Ecosystem Assessment*

Pittock, J., Meng, J. Geiger, M. , Chapagain, A.K. (2009). *Interbasin water transfers and water scarcity in a changing world - a solution or a pipedream?* WWF Germany

Tortajada, C. (2003). *Water Management for a Megacity: Mexico City Metropolitan Area*. *Ambio* 32 (2) 124-129

UNEP (2011). *Water and Cities Facts and Figures*. United Nations Environment Programme

UN HABITAT (2006). *STATE OF THE WORLD'S Cities 2006/7. The Millennium Development Goals and Urban Sustainability: 30 Years of Shaping the Habitat Agenda*. United Nations Human Settlements Programme (UN-HABITAT) & Earthscan Publishing

UN HABITAT (2008). *State of the World's Cities 2010/11. Bridging the Urban Divide*. United Nations Human Settlements Programme (UN-HABITAT) & Earthscan Publishing

UN-Water (2006). *Coping with water scarcity: a strategic issue and priority for systemwide action*. UN-Water, FAO

UN-Water (2007). *Coping with water scarcity. Challenge of the twenty-first century*. UN-Water, FAO.

Vörösmarty, C.J., C. Lévêque, C. Revenga, R. Bos, C. Caudill, J. Chilton, E.M. Douglas, M. Meybeck, D. Prager, P. Balvanera, S. Barker, M. Maas, C. Nilsson, T. Oki, C.A. Reidy (2005). Chapter 7, *Fresh Water*. In: R. Hassan, R. Scholes, N. Ash (eds.): *Ecosystems and Human Well-being: Current State and Trends, Volume 1. Millennium Ecosystem Assessment*

WHO (2008). *World Health Organization Global Burden of Disease. 2004 Update*

CHAPTER 2: WATER FOOTPRINT OF CITIES

ADB (2004). *Water in Asian Cities. Utilities' Performance and Civil Society View*. Asian Development Bank

Cruz, M. C. & Medina, R.S. (2003). *Agriculture in the City – A Key to Sustainability in Havana, Cuba*. Ian Randle Publishers, IDRC

Leach, M. & Mearns, R. (eds) (1996). *The Lie of the Land: Challenging Received Wisdom on the African Environment*. International African Institute in association with James Currey

Mafuta, C., Formo, R. K., Nellemann, C., Li, F. (eds) (2011). *Green Hills, Blue Cities: An Ecosystems Approach to Water Resources Management for African Cities. A Rapid Response Assessment*. United Nations Environmental Programme, GRID-Arendal

Sonnenberg, A., Chapagain, A., Geiger, M., August, D. (2009). *Der Wasser-Fußabdruck Deutschlands – Woher stammt das Wasser, das in unseren Lebensmitteln steckt?* WWF Deutschland. Frankfurt am Main

Yang, A.L., Rashid K., Zhao X.M., Huang X., Zhou H.H., Su M.H., Tang H.Y., Li F. (2010). *The True Cost of Coal – an Investigation into Coal Ash in China*. Greenpeace China.

CHAPTER 3: CASE STUDIES - GLOBAL MEGACITIES & WATER

MEXICO CITY

Burns, E. (coordinator) (2009). *Repensar la cuenca: la Gestión de ciclos del agua en el Valle de México*. México, DF: Universidad Autónoma Metropolitana: Centro para la Sustentabilidad Incalli Ixcahuicopa, 160p.

CADF (1993). *Una nueva estrategia para la Ciudad de México*. Comisión de Aguas del Distrito Federal, México, D.F.

City Mayor Statistics 2011. <http://www.citymayors.com/statistics/largest-cities-mayors-1.html>

CONAGUA (2011). *Estadísticas del agua en México*, edición 2011. Marzo de 2011. Comisión Nacional del Agua

CONAPO(2005). *Delimitación de las zonas metropolitanas de México 2005*. National Council for Population Mexico. Consejo Nacional de Poblacion

CCA (2011). *Gestión del Agua en las Ciudades de México*. Indicadores de Desempeño de los Sistemas de Agua Potable, Alcantarillado y Saneamiento. Second Report June 2011. Consejo Consultivo del Agua A.C.

INEGI (2011). *Información Nacional, Por Entidad Federativa y Municipios – Distrito Federal*. Available at: <http://www.inegi.org.mx/sistemas/mexicocifras/default.aspx?ent=09>. Instituto Nacional de Estadística, Geografía e Informática

OECD (2004). *OECD Territorial Reviews: Mexico City*. Policy Brief October 2004. Organization for Economic Co-operation and Development

Rojas, E., Cuadrado-Roura, J.R., Fernández Güell, J.M., eds (2008). *Governing the metropolis : principles and cases*. Inter-American Development Bank

SMA (2005). *Informe Climatológico Ambiental del Valle de México 2005*. Secretaría del Medio Ambiente, Gobierno del Distrito Federal

Sosa-Rodriguez, F.S. (2010). *Impacts of Water-management Decisions on the Survival of a City: From Ancient Tenochtitlan to Modern Mexico City*. *Water Resources Development* 26 (4), 677-689

Sosa-Rodriguez, F.S. (2010b). *Exploring the risks of ineffective water supply and sewage disposal: A case study of Mexico City*. *Environmental Hazards* 9 (2010) 135–146

Tortajada, C. (2003). *Water Management for a Megacity: Mexico City Metropolitan Area*. *Ambio* 32 (2) 124-129

Tortajada, C. (2006). *Who has access to water? Case study of Mexico City Metropolitan Area*. UNDP Human Development Report Office Occasional Paper

UNESCO World Water Assessment Programme. (2006) *Case Study: Mexico*. *World Water Development Report 2*, available at http://www.unesco.org/water/wwap/wwdr2/case_studies/pdf/mexico.pdf

BUENOS AIRES

Agua y Saneamientos Argentinos (AySA) (2009). *Trabajamos Para El Desarrollo y Bienestar De La Comunidad*. Informe al Usuario Datos a diciembre de 2009

Almansi, F., Hardoy, A., Hardoy, J. (2010). *Improving water and sanitation provision in Buenos Aires - What can a research-oriented NGO do?* International Institute for Environment and Development (IIED), Human Settlements Working Paper Series, Water – 22, June 2010

Atlas Ambiental de Buenos Aires (AABA) (2010). <http://www.atlasdebuenosaires.gov.ar>

Garzon, C., Campos, S., Machado, K., Birolo, N., Centeno, C., Jimene, J., Nuques, C. (2009). *Water and Sanitation Program for the Buenos Aires Metropolitan Area and Conurbation*. Inter-American Development Bank Loan Proposal. Approval Date: January 1 2009

GobBsAs (2004). *PLAN ESTRATEGICO BUENOS AIRES 2010*. Consejo De Planeamiento Estrategico, Ciudad De Buenos Aires, Aprobado por la Asamblea General del CoPE el 30 de Noviembre de 2004. Gobierno de Buenos Aires

INDEC (2010). *Censo Nacional de Población, Hogares y Viviendas 2010 : total del país, resultados provisionales*. - 1a ed. - Buenos Aires : Instituto. Nacional de Estadística y Censos

INDEC (2010b). *Censo Nacional de Población, Hogares y Viviendas 2010*. Presentation, Río Gallegos, 17 de diciembre de 2010. Instituto Nacional de Estadística y Censos

INDEC (2003). ¿Qué es el Gran Buenos Aires? Buenos Aires, August 2003, Revised version 2005. Instituto Nacional de Estadística y Censos

INDEC (2001). Cuadro 4.19 Provincia de Buenos Aires: 24 Partidos del Gran Buenos Aires según partido. Población en hogares por presencia de servicio en el segmento. Año 2001 & Cuadro 4.19 Ciudad de Buenos Aires según Distrito Escolar. Población en hogares por presencia de servicio en el segmento. Año 2001. Instituto Nacional de Estadística y Censos

Jordan, R., Rehner, J., Samaniego, J. (2010). Regional Panorama - Latin America Megacities And Sustainability. UN Economic Commission for Latin America and the Caribbean (ECLAC) Project Document, December 2010

UNWWAP (2007). La Plata Basin Case Study: Final Report. UN-Water/WWAP/2007/1, April 2007. UN World Water Assessment Programme

NAIROBI

Dudley, N., Stolton, S. (2003). Running Pure: The importance of forest protected areas to drinking water. World Bank/WWF Alliance for Forest Conservation and Sustainable Use.

Foster, S. and Tuinhof A. (2005). Sustainable Groundwater Management. Concepts and Tools. Kenya: The Role of Groundwater in the Water-Supply of Greater Nairobi. Case Profile Collection No. 13. GW.MATE (Groundwater Management Advisory Team). The World Bank, Washington D.C.

GoK (2010a). 2009 Kenya Population and Housing Census results. Kenya Census 2009. Government of Kenya, presentation by Hon. Wycliffe Ambetsa Oparanya, Minister of State of Planning, National Development and Vision 2030. <http://www.knbs.or.ke/Census%20Results/Presentation%20by%20Minister%20for%20Planning%20revised.pdf>

GoK (2010b). National Climate Change Response Strategy. Government of Kenya, April 2010, Nairobi.

Hoff, Holger (2008). Challenges in upland watershed management, the green-blue water approach. In:

Garrido, A., Dinar, A. (2009). Managing water resource in a time of global change, mountains, valleys and flood plains.

Li, L., Xie G.D., Cao S.Y., Luo Z.H., Humphrey, S., Cheng, S.K., Gai L.Q., Li H.Y., Ewing, B. (2010a). China Ecological Footprint - Biocapacity, cities and development. WWF China.

Mafta, C., Formo, R. K., Nellemann, C., and Li, F. (eds). (2011). Green Hills, Blue Cities: An Ecosystems Approach to Water Resources Management for African Cities. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal.

Mogaka, H., Gichere, S., Davis, R., and Hirji, R. (2006). Climate Variability and Water. Resources Degradation in Kenya: Improving Water Resources Development and Management. World Bank Working Paper No. 69. The International Bank for Reconstruction and Development/The World Bank, Washington DC.

Msafiri, P.W. (2008). Opportunities and Challenges of Implementing PES in the Water Sector: A Kenya Buyer's Perspective. NCWSC, Nairobi.

Muiruri, J. & Kaseve, C. (2008). Strategic Guidelines for Improving Water and Sanitation to the Urban Poor. Paper Presented at the Seminar on "Urban Development in Kenya: Towards Inclusive Cities". Nairobi, Kenya, November 25, 2008.

Mumma, A., Lane, M., Kairu, E., Tuinhof, A. and Hirji, R. (2011). Water Papers: Kenya Groundwater Governance Case Study. Water Unit, Transport, Water and ICT Department.

Mungai, D.N., Thenya, A., Muthee, G., Muchemi, J.K., Mworio, G., Oduori and Kimani, J. (2011). Environmental, social and economic effects of the fencing of the Aberdare Conservation Area (in prep.). A Report for the Kenya Wildlife Service, Kenya Forest Service, Rhino Ark, Kenya Forests Working Group and UNEP, Nairobi.

NCWSC (2010). Draft Strategic Plan for the Period 2010/11 to 2014/15. Nairobi City Water and Sewerage Company, Nairobi.

NCWSC & AWSB (2009). Strategic Guidelines for Improving Water and Sanitation Services in Nairobi's Informal Settlements. Nairobi City Water and Sewerage Company and Athi Water Services Board, Nairobi.

SID (2004). Pulling Apart: Facts and Figures on Inequality in Kenya. Society for International Development, Nairobi.

UN (2006). Water, a shared responsibility. The United Nations World Water Development Report - 2. Section 5, Chapter 14, Case Studies: Kenya. 483-486. UNESCO and Berghahn Books, Paris and London.

UNEP (2007). City of Nairobi Environment Outlook. UNEP and City Council of Nairobi, Nairobi.

UN-HABITAT (2001). Cities in a globalising world. Global report on human settlements 2001. United Nations Centre for Human Settlement (HABITAT). Earthscan. UK.

UN-HABITAT (2010). Solid waste management in the world's cities: water and sanitation in the world's cities 2010. United Nations Human Settlements Programme. Earthscan, London.

WRMA (2010). Preliminary Water Allocation Plan of the Nairobi Aquifer Suite: Long Term Water Resources Management Strategy. Water Resources Management Authority, Nairobi.

WRMA (2006). Groundwater Protection Policy. Proposal for a National Policy. Water Resources Management Authority, Nairobi.

KARACHI

ADB (2004). Water in Asian Cities. Utilities' Performance and Civil Society View. Asian Development Bank

ADB (2005). Karachi Megacities Preparation Project, Final Report Vol. I. Asian Development Bank

ADB (2007). Asian Water Development Outlook 2007, Country Paper Pakistan. Asian Development Bank

Ahmed, N. (2009). Institutional reforms in water supply arrangements in Karachi. Proceedings of the Institution of Civil Engineers, Issue ME3, pp. 171–178

Dudley, N. & Stolton, S. (2003). Running Pure: The importance of forest protected areas to drinking water. World Bank/WWF Alliance for Forest Conservation and Sustainable Use

Economist Intelligence Unit (2011). Asian Green City Index. Assessing the environmental performance of Asia's major cities. Siemens AG

Hawksworth, J., Thomas, H. & Anmol, T. (2009). PricewaterhouseCoopers UK Economic Outlook November 2009. PricewaterhouseCoopers

ICIMOD (2010). Climate change impacts on the water resources of the Indus Basin. International Centre for Integrated Mountain Development

Kamal, S., Channa, I., Mooraj, T.P. (2004). The Karachi Nightmare: Water, Sewerage & Sanitation Issues in a Giant Coastal City. Paper presented at Third South Asia Water Forum, Dhaka, Bangladesh, 13-15 July, 2004

Master Plan Group of Offices (2007). Karachi Strategic Development Plan – 2020, City District Government Karachi

Mustafa, D. (2007). Social Construction of Hydropolitics: The Geographical Scales of Water and Security in the Indus Basin. The Geographical Review Vol. 97/4, pp. 484-501

Wong, C.M., Williams, C.E., Pittock, J., Collier, U., Schelle, P. (2007). World's top 10 rivers at risk. WWF International. Gland, Switzerland.

WWF Pakistan (2007). Pakistan's Waters at Risk- Water & Health Related Issues in Pakistan. Freshwater & Toxics Programme, WWF – Pakistan

KOLKATA

Adel, M. (2001). Effect on Water Resources from Upstream Water Diversion in the Ganges Basin. Journal of Environmental Quality, Vol. 30, pp. 356–368

ADB (2007). 2007 Benchmarking and Data Book of Water Utilities in India. Asian Development Bank

Chakraborti, D., Das, B., Rahman, M.M., Chowdhury, U.K., Biswas, B., Goswami, A.B., Nayak, B., Pal, A., Sengupta, M.K., Ahamed, S., Hossain, A., Basu, G., Roychowdhury, T., Das, D. (2009). Status of groundwater arsenic contamination in the state of West Bengal, India: A 20-year study report. Molecular Nutrition & Food Research, Vol. 53, Issue 5, pp. 542-551

Chakravarti, I. (undated). Water Problems for Kolkata Metropolitan Region.

Chaudhuri, S.R. & Thakur, A.R. (2006). Microbial Genetic Resource Mapping of East Calcutta Wetlands. Current Science, Vol. 91, No. 2, pp. 212-217.

Dudley, N. & Stolton, S. (2003). Running Pure: The importance of forest protected areas to drinking water. World Bank/WWF Alliance for Forest Conservation and Sustainable Use

Economist Intelligence Unit (2011). Asian Green City Index. Assessing the environmental performance of Asia's major cities. Siemens AG

Hawksworth, J., Thomas, H., Anmol, T. (2009). PricewaterhouseCoopers UK Economic Outlook November 2009. PricewaterhouseCoopers

Hazra, S. (2010). Temporal change detection (2001-2008) of the Sundarban. Unpublished report. WWF-India

Majumdar, C. & Gupta, G. (2007). The Debate over Municipal Water Pricing: Evidence from Kolkata, India. *International Journal of Water Resources Development*, Vol. 23/4, pp. 571-582

McKenzie, D. & Ray, I. (2009). Urban water supply in India: status, reform options and possible lessons. *Water Policy*, Vol. 11, No. 4, pp. 442-460

Sagane, R. (2000). Water management in mega-cities in India: Mumbai, Delhi, Calcutta, and Chennai, in: Uitto J.I. & A.K. Biswas (2000). *Water for Urban Areas, challenges and perspectives*. United Nations University Press

Salman, S. M. A.; Uprety, K. (2003). Conflict and cooperation on South Asia's international rivers: a legal perspective. *World Bank Publications*. pp. 135-136.

Vörösmarty, C.J., Lévêque, C., Revenga, C., Bos, R., Caudill, C., Chilton, J., Douglas, E.M., Meybeck, M., Prager, D., Balvanera, P., Barker, S., Maas, M., Nilsson, C., Oki, T., Reidy, C.A. (2005). Chapter 7, Fresh Water. In: Hassan, R., Scholes, R., Ash, N. (eds.): *Ecosystems and Human Well-being: Current State and Trends, Volume 1. Millennium Ecosystem Assessment*

Wetlands International (2010). *Wetlands and Water, Sanitation and Hygiene (WASH) – understanding the linkages*. Wetlands International, Ede, the Netherlands.

WWF India (2010). *The Mega-city of Kolkata and its impact on Ecological Systems*.

WWF India (2011). *Impacts Of Urbanisation In Biodiversity Hotspot Regions Of India, Scoping Study*.

SHANGHAI

ADB (2010). *Wastewater Treatment: Case Study of Public-Private Partnerships (PPPs) in Shanghai*. Urban Innovations and Best Practices. Asian Development Bank, November 2010. www.adb.org/urbandev.

Chapagain, A.K. & Orr, S. (2008). UK Water Footprint: the impact of the UK's food and fibre consumption on global water resources. WWF UK, Godalming, UK.

Economist Intelligence Unit (2011). Asian Green City Index. Assessing the environmental performance of Asia's major cities. Siemens AG, Germany 2011.

Fu, T., Chang, M., Zhong, L. (2008). *Reform of China's Urban Water Sector*. London: IWA Publishing Limited.

Ge, H.Z. (1998). *Surface Water Pollution and Control in Shanghai*. Online: Shanghai Environment Center, www.envir.gov.cn/wp/index.asp.

Jiang, L., Hu, X.L., Yin, D.Q., Zhang, H.C., Yu, Z.Y. (2011). Occurrence, distribution and seasonal variation of antibiotics in the Huangpu River, Shanghai, China. *Chemosphere* 82/2011: 822-828.

Kung Hsiang, T. & Ying Long, G. (1991). A study of lake eutrophication in Shanghai, China. *Geographical Journal* 157(1)/1991:45-50.

Li, L., Xie G.D., Cao S.Y., Luo Z.H., Humphrey, S., Cheng, S.K., Gai L.Q., Li H.Y., Ewing, B. (2010a). *China Ecological Footprint - Biocapacity, cities and development*. WWF China.

Li, T.L., Gao, X.Y., Zhang, X.Z., Wang, Y.S. (2010b). Impact of runoff on salt intrusion of Yangtze estuary. *Proceedings of the International Conference on Coastal Engineering*, No 32/2010.

Ren, W.W, Zhong, Y., Meligrana, J., Anderson, B., Watt, W.E., Chen, J.K, Leung, H.L. (2003). Urbanization, land use, and water quality in Shanghai 1947-1996. *Environment International* 29/2003: 649- 659.

Ren, W.W., Meligrana, J., Zhang, Z.Y., Anderson, B. (2008). Balancing Economic Development and the Preservation of Agricultural Land: An Evaluation of Shanghai's Municipal Land Use Plan. *Urban Policy and Research* 26(4): 481-496.

Ward, R.M. & Liang, W. (1995). Shanghai water supply and wastewater disposal. *Geographical Review* 85/1995:141-56.

WHO/UNEP (1997). Water Pollution Control - A Guide to the Use of Water Quality Management Principles. Case Study II - Shanghai Huangpu River, China. United Nations Environment Programme, the Water Supply and Sanitation Collaborative Council and the World Health Organization.

WWF China (2009). Water Source Protection – WWF Demonstration Project of Wetland Restoration in Dalian Lake. WWF Shanghai water source protection project, HSBC Climate Partnership – WWF China Programme Shanghai.

Xu, Y.P., Xu, J.T., Ding, J.J., Chen, Y., Yin, Y.X., Zhang, X.Q. (2010). Impacts of urbanization on hydrology in the Yangtze River Delta. *Water Science & Technology* 62.6/2010: 1221-1229.

Yang, H.J. Shen, Z.M., Zhang, J.P., Wang W.H. (2007). Water quality characteristics along the course of the Huangpu River (China). *Journal of Environmental Sciences* 19/2007: 1193–1198.

Yin, J., Yin, Z., Zhong, H.D., Xu, S.Y., Hu, X.M., Wang, J., Wu, J.P. (2010). Monitoring urban expansion and land use/land cover changes of Shanghai metropolitan area during the transitional economy (1979–2009) in China. *Environmental Monitoring and Assessment* 177/2011:609–621.

Zhang, H. (2007). The orientation of water quality variation from the metropolis river–Huangpu River, Shanghai. *Environmental Monitoring and Assessment* 127/2007:429–434.

Zhao, S. Q., Da, L. J., Tang, Z. Y., Fang, H.J., Song, K., Fang, J.Y. (2006). Ecological consequences of rapid urban expansion: Shanghai, China. *Frontiers in Ecology and the Environment* 4(7): 341–346.

Zheng, M.H., Liu, S.H., Jiang, S.M. (2011). Influence of major hydraulic projects on saltwater intrusion in the Yangtze River estuary. *Goldschmidt Conference Abstracts, Global Water Sustainability*

CHAPTER 4: CONCLUSIONS

Allan, J.A. (1993). Fortunately there are substitutes for water: Otherwise our hydro-political futures would be impossible. In: *Priorities for Water Resources Allocation and Management*, ODA, London, UK, pp. 13–26

Bhatia, R., Falkenmark, M. (1992). Water resource policies and the urban poor: innovative approaches and policy imperatives. Background paper prepared for the ICWE, Dublin, 26-31 January 1992

CDP (2011). CDP Cities 2011 Global Report on C40 Cities. KPMG Advisory N.V. & Carbon Disclosure Project

Economist Intelligence Unit (2010). Latin American Green City Index: Assessing the environmental performance of Latin America's major cities. Siemens AG

Economist Intelligence Unit (2011). German Green City Index- Analyse der Leistungen zwölf deutscher Großstädte im Bereich Umwelt- und Klimaschutz. Siemens AG

Garzon, C., Campos, S., Machado, K., Birolo, N., Centeno, C., Jimene, J., Nuques, C. (2009). Water and Sanitation Program for the Buenos Aires Metropolitan Area and Conurbation. Inter-American Development Bank Loan Proposal. Approval Date: January 1 2009

Ma, J.A., H. Hoekstra, A. Wang, A.K. Chapagain, D. Wang (2006). Virtual versus real water transfers in China. *Philosophical Transactions of The Royal Society. London B. Issue 361*, pp. 835-842

Matthews, J., Quesne, T. (2009). *Adapting Water Management - A primer on coping with climate change*. WWF Water Security Series 3. WWF - UK

McGranahan, G., P. Marcotullio, X. Bai, D. Balk, T. Braga, I. Douglas, T. Elmqvist, W. Rees, D. Satterthwaite, J. Songsore, H. Zlotnik, J. Eades, E. Ezcurra (2005). Chapter 27, Urban Systems. In: R. Hassan, R. Scholes, N. Ash (eds.): *Ecosystems and Human Well-being: Current State and Trends, Volume 1. Millennium Ecosystem Assessment*

Mekonnen, M.M., Hoekstra, A.Y. (2011). National water footprint accounts: the green, blue and grey water footprint of production and consumption. *Value of Water Research Report Series No. 50*, UNESCO-IHE, Delft, the Netherlands

Pitcock, J., Meng, J., Geiger, M., Chapagain, A. K. (2009). Interbasin water transfers and water scarcity in a changing world - a solution or a pipedream? WWF Germany

Scott, C., Banister, J. (2008). The Dilemma of Water Management 'Regionalization' in Mexico under Centralized Resource Allocation. *Water Resources Development* 24 (1), 61–74

Sosa-Rodriguez, F. (2010). Impacts of Water-management Decisions on the Survival of a City: From Ancient Tenochtitlan to Modern Mexico City. *Water Resources Development* 26 (4), 677-689

Tortajada, C. (2006). Who has access to water? Case study of Mexico City Metropolitan Area. UNDP Human Development Report Office Occasional Paper

UNEP (2011). Water and Cities Facts and Figures. United Nations Environment Programme

Vörösmarty, C.J., C. Lévéque, C. Revenga, R. Bos, C. Caudill, J. Chilton, E.M. Douglas, M. Meybeck, D. Prager, P. Balvanera, S. Barker, M. Maas, C. Nilsson, T. Oki, C.A. Reidy (2005). Chapter 7, Fresh Water. In: R. Hassan, R. Scholes, N. Ash (eds.): Ecosystems and Human Well-being: Current State and Trends, Volume 1. Millennium Ecosystem Assessment

WHO (2008). World Health Organization Global Burden of Disease. 2004 Update

Wouters, P. (2010). Water Security: Global, regional and local challenges. Institute for Public Policy Research

WWAP (2006). The United Nations World Water Development Report 2: Water – a shared responsibility. UNESCO and Berghahn Books. World Water Assessment Programme

WWF (2006). Payments for Environmental Services- An equitable approach for reducing poverty and conserving nature. World Wide Fund For Nature, Gland, Switzerland

FOOTNOTES

- 1 http://www.un.org/waterforlifedecade/water_cities.html
- 2 http://www.unesco.org/water/wwap/facts_figures/water_cities.shtml
- 3 See <http://www.gdrc.org/uem/footprints/index.html> for urban footprints (not specific to water)
- 4 <http://berliner-wassertisch.net/>
- 5 www.waterfootprint.org
- 6 <http://www.inegi.org.mx>
- 7 <http://www.citymayors.com/statistics/largest-cities-mayors-1.html>
- 8 author's calculation, based on 2000 and 2010 census data, www.inegi.org.mx
- 9 based on conversion rate from January 1, 2011; www.oanda.com
- 10 <http://www.foodbev.com/report/bottled-water-in-mexico-second-in-the-world>
- 11 <http://www.conagua.gob.mx/Default.aspx>
- 12 ibid
- 13 <http://www.conagua.gob.mx/ocavm/Espaniol/TmpContenido.aspx?id=5e5c0cc2-be94-43ff-b1c1-1b671ee1b316|Acerca%20de%20la%20Cuenca%20de%20Cuenca%20de%20Cuenca>
- 14 See http://www.wwf.org.mx/wwfmex/prog_cuenas.php for more information.
- 15 Atlas Ambiental de Buenos Aires, <http://www.atlasdebuenosaires.gov.ar>
- 16 ibid
- 17 <http://www.cedom.gov.ar/es/ciudad/barrios/ciudad/ciudad.html>
- 18 <http://worldweather.wmo.int/050/c00294.htm>
- 19 ibid
- 20 <http://www.blacksmithinstitute.org/>
- 21 further information on the court case is available in English at: http://www.farn.org.ar/participacion/riachuelo/resumen_in-ingles.html
- 22 More information on FARN's role is available at: <http://www.farn.org.ar/riachuelo/caso.html>.
- 23 <http://esa.un.org/unpd/wup/index.htm>
- 24 according to Köppen climate classification
- 25 all climate data for Nairobi: World Meteorological Organization <http://worldweather.wmo.int/071/c00251.htm>
- 26 http://www.nairobiwater.co.ke/about_us/?ContentID=1
- 27 prices in US\$ are based on the currency rate in August 2011.
- 28 <http://www.awsboard.go.ke/page.php?id=18>
- 29 http://www.nairobiwater.co.ke/water_quality/?ContentID=7
- 30 http://www.nairobiwater.co.ke/about_us/?ContentID=1
- 31 http://www.nairobiwater.co.ke/water_quality/?ContentID=4
- 32 http://www.nairobiwater.co.ke/water_quality/?ContentID=7
- 33 http://www.nairobiwater.co.ke/water_quality/?ContentID=7
- 34 <http://www.awsboard.go.ke/>
- 35 <http://allafrica.com/stories/201006170010.html?viewall=1>
- 36 http://www.nairobiwater.co.ke/about_us/?ContentID=1
- 37 average monthly income in Nairobi's informal settlements is 3,000 KSH (NCWSC & AWSB, 2009)
- 38 http://www.nairobiwater.co.ke/water_quality/?ContentID=4
- 39 <http://greenwatercredits.info/>

40 <http://www.citymayors.com/statistics/largest-cities-mayors-1.html>

41 <http://www.karachicity.gov.pk/>

42 <http://www.karachicity.gov.pk/>

43 <http://www.karachicity.gov.pk/>

44 <http://www.karachicity.gov.pk/>

45 <http://www.karachicity.gov.pk/>

46 http://www.hko.gov.hk/wxinfo/climat/world/eng/asia/westasia/karachi_e.htm

47 <http://worldweather.wmo.int/047/c00892.htm>

48 <http://www.kwsb.gos.pk/water.asp>

49 <http://www.kwsb.gos.pk/budget.asp>, currency conversion through OANDA, at conversion rates from 29th June 2011, date of the budget announcement

50 <http://asianetpakistan.com/official-news/7438>, currency conversion through OANDA, at conversion rates from 29th June 2011, date of the budget announcement

51 <http://www.dawn.com/2011/03/22/water-woes-in-karachi.html>

52 <http://www.dawn.com/2011/03/22/water-woes-in-karachi.html>, currency conversion through OANDA based on rates from 11th March 2011, date of news article

53 <http://www.oppinstitutions.org/>

54 <http://www.hisaar.org>

55 <http://foreverindus.org>

56 <http://www.citymayors.com/statistics/largest-cities-mayors-1.html>

57 <https://www.kmcgov.in/KMCPortal/jsp/KolkataStatistics.jsp>

58 <http://www.asiarooms.com/en/travel-guide/india/kolkata/kolkata-overview/kolkata-population.html>

59 <http://www.rediff.com/money/2008/jan/29gdp.htm>

60 <http://www.tribuneindia.com/2003/20030714/agro.htm#2>

61 <https://www.kmcgov.in/KMCPortal/jsp/KolkataStatistics.jsp>

62 <http://www.weatherbase.com/weather/weatherall.php3?s=090824&refer=&units=metric>

63 <http://www.weatherbase.com/weather/weatherall.php3?s=090824&refer=&units=metric>

64 <https://www.kmcgov.in/KMCPortal/jsp/WaterSupply.jsp>, currency conversion through OANDA, at conversion rates from 29th June 2011, date of the budget announcement

65 <https://www.kmcgov.in/KMCPortal/jsp/WaterSupply.jsp>, currency conversion through OANDA, at conversion rates from 29th June 2011, date of the budget announcement

66 <http://business.rediff.com/slide-show/2010/apr/23/slide-show-1-the-top-10-cities-in-india-by-gdp.htm>

67 <http://www.aaas.org/international/ehh/waterpop/bang.htm>

68 <http://kmwsa.gov.in/html/retros.html>

69 <http://kmwsa.gov.in/html/cdp-kma.html>

70 <http://www.hmc.org.in/home/watersupply.php>

71 <http://jnurm.nic.in/nurmudweb/toolkit/KolkataCdp/CH-I50-123.pdf>

72 <http://kmwsa.gov.in/html/retros.html>

73 The 1980s plan by the government for developing good drainage system for the city has stopped mid way, due to various legal complications making the system of natural detoxification of the sewage less useful

74 <http://kmwsa.gov.in/html/retros.html>

75 <http://www.keip.in/bl3/aboutus.php>

76 <http://www.business-standard.com/india/news/kolkata-assumes-domestic-water-supply-is-free/380556/>

77 http://www.wbpcb.gov.in/html/pressrelease/report_rwh.pdf

78 <http://www.ekwma.com/index.php?view=default&MenuID=20>

79 http://www.wfindia.org/about_wwf/critical_regions/sundarbans/

80 <http://www.stats.gov.cn/tjgb/rkpcgb/index.htm>

81 http://www.stats.gov.cn/english/newsandcomingevents/t20110429_402722516.htm

82 calculation of average annual population growth is based on a population of 16,737,734 in 2000 according to the 2000 census

83 <http://www.shanghai.gov.cn/shanghai/node23919/node24059/node24061/userobject22ai36487.html>

84 ibid

85 all climate data from <http://worldweather.wmo.int/071/c00251.htm>

86 www.un.org/cyberschoolbus/habitat/profiles/shanghai.asp

87 all prices in US\$ are based on the currency rate in August 2011.

88 http://www.shanghaiwater.gov.cn/swEng/useful/water_standard.jsp?flag=4&loation=2&type=3

89 <http://www.yangtzeforum.com/aboutus-eng.asp>

90 http://www.shanghaiwater.gov.cn/swEng/government/government_LR/laws_detail3.jsp?type=2&loation=1

91 http://news.xinhuanet.com/english2010/indepth/2011-05/26/c_13894702.htm

92 <http://english.sina.com/china/p/2011/0525/374921.html>

93 Shanghai Daily, 16th of January 2008, p.5.

94 <http://www.shanghaiwater.gov.cn/swEng/gs!getGssllsAndNo.action>

95 http://www.shanghaiwater.gov.cn/swEng/useful/water_standard.jsp?flag=4&loation=2&type=3

96 http://english.mep.gov.cn/standards_reports/standards/water_environment/

- 97 “Budget implementation in 2010, Shanghai, and 2011 draft budget report” and “Shanghai municipal department budget in 2011 (Summary)” <http://christianlouboutincoach.blogge.rs/2011/01/23/shanghai-budget-transparency-bill-land-income-and-livelihood-support/>
- 98 http://www.shanghaiwater.gov.cn/swEng/useful/water_standard.jsp?flag=4&loation=2&type=3
- 99 <http://www.chinafinancialdaily.com/financial/news/2011/03/25/13881/2010-shanghai-average-monthly-wage-3896-yuan-the-annual-average-wage-of-46757-yuan.html>
- 100 <http://china.globaltimes.cn/society/2011-04/629414.html>
- 101 <http://www.shtong.gov.cn/node2/node82288/node82501/node82504/userobject1ai113520.html>
- 102 <http://china.globaltimes.cn/society/2011-05/659148.html>
- 103 <http://www.shanghaidaily.org/nsp/Metro/2011/06/04/Salt%2BTide%2BBack%2BTomorrow/>, http://www.chinadaily.com.cn/china/2011-05/26/content_12581749.htm
- 104 not taking into consideration existing campaigns to create awareness to improve and minimize water consumption
- 105 http://www.chinadaily.com.cn/china/2011-05/26/content_12581749.htm
- 106 http://china.globaltimes.cn/society/2011-05/659148_2.html
- 107 WWF Shanghai
- 108 <http://wwf.panda.org/?162642/Yangtze-estuary-gets-a-welcome-focus-from-river-forum>
- 109 <http://www.rainwaterharvesting.org>
- 110 <http://www.waterfootprint.org/?page=files/productgallery>
- 111 http://wwf.panda.org/about_our_earth/about_freshwater/rivers/irbm/
- 112 <http://www.yangtzeforum.com/aboutus-eng.asp>

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