

Perspectives on water and climate change adaptation

Local government perspective on adapting water management to climate change



World Water Council
World Water Forum



co-operative programme
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This Perspective Document is part of a series of 16 papers on «Water and Climate Change Adaptation»

‘Climate change and adaptation’ is a central topic on the 5th World Water Forum. It is the lead theme for the political and thematic processes, the topic of a High Level Panel session, and a focus in several documents and sessions of the regional processes.

To provide background and depth to the political process, thematic sessions and the regions, and to ensure that viewpoints of a variety of stakeholders are shared, dozens of experts were invited on a voluntary basis to provide their perspective on critical issues relating to climate change and water in the form of a Perspective Document.

Led by a consortium comprising the Co-operative Programme on Water and Climate (CPWC), the International Water Association (IWA), IUCN and the World Water Council, the initiative resulted in this series comprising 16 perspectives on water, climate change and adaptation.

Participants were invited to contribute perspectives from three categories:

- 1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and ‘Deltas and coastal cities’ (13).
- 2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), ‘Water supply and sanitation: the urban poor’ (7), Business (8), Water industry (10), Energy (12) and ‘Water supply and sanitation’ (14).
- 3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and ‘Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)’ (16).

The consortium has performed an interim analysis of all Perspective Documents and has synthesized the initial results in a working paper – presenting an introduction to and summaries of the Perspective Documents and key messages resembling each of the 16 perspectives – which will be presented and discussed during the 5th World Water Forum in Istanbul. The discussions in Istanbul are expected to provide feedback and come up with suggestions for further development of the working paper as well as the Perspective Documents. It is expected that after the Forum all documents will be revised and peer-reviewed before being published.

Local government perspective on adapting water management to climate change

Note: This paper does not address the core challenge of meeting the MDGs for water and sanitation. The paper only looks at additional vulnerabilities and possible adaptation strategies in relation to climate change. This paper also has an urban focus and is more relevant to cities than to the types of local authorities that serve rural or agricultural communities. Sources for the information in this paper are generally appended but not footnoted.

Local government perspective on adapting water management to climate change

Cities and other local authorities have a critical stake in the adaptation of water management to a changing climate. Virtually all the world's future population growth is predicted to take place in cities and their urban landscapes. The UN estimates a global increase from the 2.9 billion urban residents in the 1990s to a staggering 5.0 billion by 2030. By 2030, 1 in 4 persons will live in a city of 500,000 people, and 1 in 10 will live in a mega-city of 10 million or more. How will climate change and variability affect water services and water safety for these many millions? What actions should local governments take to adapt water management for climate change?

Many impacts of climate change do not create new risks but increase risk levels of existing hazards. Well-resourced cities already have programmes to protect their citizens and capital assets from at least the current range of hazards. But there is a wide variance in the adaptive capacities of city governments, including their accessible information base, existing infrastructure, quality of institutions and governance, and financial and technical resources. The Adaptation Agenda that emerges from the Fifth Forum must be realistic about the range of local government capabilities.

The Third World Water Development Report (Draft) points out that in many cities the innovation that is needed is not to invent but to apply proven water management measures. The Report notes that adaptation to climate change can best begin by improvements in adaptation to current climate, including its variability and extremes. Thus adaptation begins with measures which largely should have been taken anyway.

Cities must have access to locally-relevant climate projections and support in scenario-building/modeling of uncertainties for taking appropriate decisions. The cases that follow indicate how a few cities have obtained tailored climate information and have begun adaptation planning. The Istanbul Water Consensus and ICLEI's Climate-Resilience Guidebook provide a flexible framework for city leaders to assess climate change vulnerabilities and develop adaptation strategies (ICLEI, 2007).

Virtually all urban centres in high-income nations have the powers and resources to meet high standards of climate resilience, but there are still political, institutional and financial constraints on the ability of local governments to develop appropriate

climate change adaptation policies, especially in low- and middle-income countries. The importance of good local governance can hardly be overstated. Where the institutional capacity to manage urbanization and provide equitable and quality public service is lacking, large populations of the urban poor will be increasingly vulnerable to climate-induced risks. National governments and development assistance agencies need to engage with cities to help ensure that each city has the necessary competence, authority, funding and accountability. The Adaptation Agenda must pledge these essential resources.

Five areas of urban vulnerability to climate change are summarized here, recognizing that the range of risks to each city will differ. These summaries respond to the key question from the perspective of city leaders: *Where will climate change hit water resources and water services the hardest?* The adaptation strategies and city examples that follow highlight the political and practical challenges for local officials, responding to the key questions:

- how to translate knowledge to decision-making;
- how to identify and prioritize adaptation measures;
- how to secure financial commitment; and
- how climate change may positively shape water sector development.

1 Infrastructure inadequacy

Climate Impacts and Vulnerability

Because cities support dense human development, they generally develop highly engineered systems to provide water supply, sewage disposal and storm

drainage. Urban infrastructure is sized and engineered based on historic weather norms. In many cities, this existing infrastructure is under tremendous stress first, because of unprecedented urban population increases, and second, because systems are reaching the end of their 50-100 year service life-span.

Climate change and variability introduce a whole new set of vulnerabilities for cities with existing infrastructure. In many cities, systems engineered to handle a historic range of weather conditions will not be adequate for the variability and intensity of future weather events.

However, a portion of the urban population in low- and middle-income nations has no infrastructure to adapt – no all-weather roads, piped water or drains – and lives in temporary or poor quality housing on floodplains or on landslide-prone slopes. In the mega-cities and ‘million cities’ of the developing world, informal settlements and slums – home to around one billion urban dwellers - are less likely to have drinking water and sanitary services, or provisions for storm drainage. They are more vulnerable to water-related disasters, such as floods and severe storms, and water-borne diseases. Climate change increases these risks.

Cities that currently lack piped water, drainage and sewage facilities now face the additional costs of designing and sizing new systems to accommodate an uncertain climate future. Existing infrastructure may be of poor quality due to faulty construction, corruption in contracting, lack of funding or technical skills for maintenance, or ineffective regulatory mechanisms. Furthermore, as marginal lands in peri-urban areas are built out with temporary or low-quality structures, locating and financing the systems to provide water, drainage, and sanitation under future climate conditions becomes more problematic.

Strategies

Adaptation planning – Climate adaptation processes launched by a number of cities and urban regions, and incorporated in the Istanbul Urban Water Consensus, share the following elements:¹

¹ Based on: IWC, www.worldwaterforum5.org; ICLEI (2007) and Clean Air Partnership (2007).

- Measures to increase public awareness and engage stakeholders;
- Systematic review of climate trends and projections for the specific urban region, and range of likely impacts;
- Assessment of water system vulnerabilities and potential costs of climate impacts;
- Identification of a range of options for reducing vulnerabilities, building on existing programmes, where possible;
- Development and implementation of adaptation strategy.

Progressive infrastructure redesign – Cities that have assessed risks and set priorities can begin incorporating changes based on climate impacts into long-lived infrastructure projects, re-engineering and resizing as necessary. Most buildings and infrastructure have long lives; what is built now should be designed to cope with climate-induced risks for decades. Similarly, repairs and reconstruction that follow major extreme weather events can incorporate extra protection for future climate patterns that promise more of the same. The working principle is that infrastructure must be designed for the climate anticipated throughout the planned lifetime of the improvement, not just for the climate when it is built. Thus adaptation measures will be merged with ongoing natural hazard risk reduction and urban renewal interventions.

Nested closed-loop systems – A complementary strategy is one of nesting self-contained systems into the broader city system. By dealing with the ecological footprint at the parcel level, semi-autonomous ‘demand management’ developments can be created that will deal with their own infrastructure needs on site, including water supply, stormwater control, sewage treatment, thermal demand for heating and cooling and electrical demands. Creating these nested systems will buffer the demand on centralized infrastructure and add system robustness and resilience – all necessary in a world with increased uncertainty in climate effects on infrastructure.

Community action – Community-based adaptation strategies seek to harness the autonomous risk-reduction energies of urban communities. Federations of the urban poor, active in a number of nations, involve communities in many initiatives to

upgrade housing, reduce risk from disasters, and improve provision for water, sanitation and drainage. Participatory community action can increase resilience to current disasters, for example, by building houses on stilts, replanting coastal lowlands, digging and maintaining drainage ditches within the settlement. However, city-level commitment is needed for city-wide trunk infrastructure to effectively complete the adaptation for climate change.

Case 1: Durban – Merging adaptation and risk reduction²

With 3.5 million people, Durban is South Africa's third largest city and largest port. Under projected climate change scenarios, Durban faces heat waves, constraints on water supply, extreme weather events, river flooding, sea-level rise, and bio-hazards such as algal blooms. In 2006, the Environmental Management Department of eThekweni Municipality (Durban) produced a 'Headline Climate Change Adaptation Strategy' resulting from detailed discussion with municipal line departments. Working with the Council for Scientific and Industrial Research (CSIR) and with the Tyndall Centre for Climate Change Research in the UK, Durban is developing a model for simulation, evaluation and comparison of strategic development plans in the context of climate change. The aim is to incorporate climate change into all long-term city planning.

The Durban plan demonstrates the relevance of climate change for virtually all city agencies but in particular addresses the infrastructure needed to provide appropriate water management.

- Improve urban drainage and adjust storm-sewer design;
- Revise construction standards for key infrastructure such as coastal roads;
- Reduce vulnerability of sewage networks and informal settlements to flooding during extreme weather events;
- Develop a shoreline management plan to manage and defend the coastline and its infrastructure;
- Increase water-absorbing capacity of urban landscapes; utilize stormwater retention ponds and constructed wetlands;

Raise the height of shoreline stabilization measures.

² Based on: Satterthwaite et al. (2007), pp. 55–58.

Durban suffered several major storms subsequent to producing the Headline Climate Change Adaptation Strategy. High tides and waves in March 2007 resulted in extensive damage to municipal infrastructure along the coast and increased the urgency for implementing the strategy.

Case 2: New York City - Incorporating climate change in infrastructure planning³

New York City has one of America's most extensive municipal water systems, bringing water from distant watersheds to serve 8 million people. The system is over 100 years old and showing its age. Two immense water tunnels under the city were opened in 1917 and 1936 and have not been inspected since. Major infrastructure renewal and expansion is overdue.

New York City established a Climate Change Task Force in 2003 involving representatives from seven city departments, including water supply, water and sewer operations, and wastewater treatment. Researchers from Columbia University's Earth Institute and other linked academic institutions worked closely with City agencies to identify the range of sea-level rise, extremes of heat, precipitation intensity and other vulnerabilities.

Based on this assessment, the City of New York incorporated a number of water management adaptation measures in its 2007 city plan:

- Tighter drought regulations, to be promptly ratcheted up in the event of drought;
- Construction of increased redundancy in the water supply infrastructure;
- Construction of floodwalls around low-lying wastewater treatment plants to protect against higher storm surges;
- Integration of the New York City water supply system with other regional systems to increase flexibility in the event of localized disruptions;
- Increased urban rainwater absorption through aggressive tree planting and green roof initiatives.

These measures are supported by numerical targets and budget commitments. Climate change considerations are mainstreamed into city projects and

³ Based on: City of New York (2007).

maintenance. The indicated infrastructure upgrades will be phased in as part of planned renewal.

New York has also begun to permit decentralized closed-loop systems in new high-rise developments. Using membrane bioreactor systems for wastewater treatment and reuse, along with rainwater harvesting, such developments dramatically reduce on-site demand for potable water and use of sewer and storm drains, thus deferring the need to expand infrastructure.

Key questions

How can the gap between available knowledge and concrete decision-making be closed?

Both Durban and New York City demonstrate the importance of locally-relevant climate projections, assessment of infrastructure deficits and identification of ‘no regrets’ measures to be incorporated in on-going system development and renewal. In each case, (1) the city partnered with climate researchers to obtain tailored climate information. Then (2) all city agencies were engaged in identifying likely climate impacts on specific governmental services. This analysis and administrative buy-in provides a firm basis for (3) mainstreaming climate considerations into infrastructure investments and project reviews, notwithstanding the inherent uncertainty of climate projections.

Large cities of the developed world generally have strong links to research universities -- an important asset in projecting localized climate impacts and vulnerabilities. Cities that own and manage their own water, sewer and drainage infrastructure (like New York City) have a direct stake in such planning. But cities served by private sector water companies (like London) or by other public authorities (like Melbourne) have also taken leadership in developing adaptation programmes. All have found ways to bridge the gap between available knowledge and concrete decision-making through partnerships among academics, civil society, the business community and government at multiple levels.

Associations of cities have now begun to address the climate adaptation process. ICLEI has published a climate resilience manual. The Istanbul Water Consensus, supported by city associations UCLG and ICLEI, engages city elected leaders in undertaking vulnerability assessments and adopting adaptation

strategies. The Adaptation Agenda should recognize and support such networked capacity-building.

What is required to secure and direct investments?

The cases demonstrate the necessity for a first level of investment in vulnerability assessment, adaptation planning and social marketing. Some ‘no regrets’ or low-cost/ immediate-benefit measures may emerge from that process. However, water service and water safety infrastructure is capital intensive. In most cities it will be unrealistic to finance the indicated infrastructure development or upgrades on a full-cost-recovery basis. Even in developed countries, national or international grants or loans will generally be required to make up the difference.

Furthermore, for informal or illegal settlements, there are multiple disincentives for infrastructure investment by either government or landowners or inhabitants. Intractable land tenure issues and housing already on the ground make locating and constructing infrastructure prohibitively difficult. Because poor populations lack political clout, and because the importance of their contribution to city economies is undervalued, infrastructure needs in poor neighborhoods are too often ignored.

New York City’s experience with decentralized closed-loop systems points up another barrier to investment – regulatory and health standards that are geared to traditional engineering solutions and may not allow innovations. A city may not be able to access financing for non-conventional solutions.

2 Inundation risks

Climate Impacts and Vulnerability

For ease of trade and commerce, many of the world’s great human settlements have been built on deltas, along coastlines or along river flood plains. Climate change makes these cities particularly vulnerable to water-related disasters. Sea-level rise and more intense storms will increase vulnerability to marine-induced disasters from tidal waves and storm surges. River flooding may be intensified by glacial melt-off and catastrophic rains. At the same time, higher sea level and lowered groundwater tables from pumping for urban use will result in salt water intrusion and

compromised urban water supplies. Transportation infrastructure is at great risk – sea ports, low-lying airports, coastal highways and railroads, bridges subject to scour, subways and tunnels vulnerable to flooding. Residential development in river valleys and along sea coasts may become unsustainable. The lives and livelihoods of the urban poor are likely to be most severely impacted.

Cities at greatest risk must urgently reconsider nearly every aspect of planning, management, zoning, infrastructure and building codes. This will require a detailed documentation of the elevation of infrastructure elements; susceptibility of coastal, wetland and artificial fill areas to erosion; defining areas of potential pollution and contamination release; determining changing drainage and storm surge risk; assessing structural viability of buildings and levees; looking at the future of fresh potable water sources with changing groundwater levels and saline water intrusion; defining the modifications necessary to maintain connectivity of roadways; and many other aspects.

Many cities in the developing world lack effective and enforceable spatial planning and development regulations. In poorly-managed cities, buildings and roads may have been constructed that actually encroach on drains, fill up natural watercourses, or obstruct planned utility easements. Where solid waste management is inadequate, garbage quickly clogs drains and ditches, causing stormwater backup with even moderate rainfall. Land use regulation, drains maintenance and solid waste management are first steps to reduce current flood risks and provide a base for adaptation to a riskier future.

Changes in spatial planning and building codes, together with the need to assist re-settlement in some cases, present unprecedented challenges for local government, especially where people are too poor to have viable options, where communities have lost resilience from repeated disasters, or where commercial interests exert political pressure for imprudent development. The response to Hurricane Katrina demonstrates how politically difficult or impossible it may be to persuade people to rebuild in less vulnerable areas, a difficulty compounded when no other affordable land is available.

Strategies

Disaster management – Disturbances caused by extreme weather can be highly disruptive of daily municipal services, destroying public property and infrastructure, and requiring intense local rescue and restoration measures. In emergency, people turn to their local authorities for help. There are potential synergies between reducing climate change risks, strengthening disaster preparedness, and mitigating other environmental risks. Early warning systems and community disaster preparedness must be a local government priority for a city facing flood risks.

Risk analysis – Local governments have a significant impact on long-term community development and hazard mitigation; they can influence the degree of community vulnerability to climate change impacts. A first step is assessing vulnerability. Composite risk assessments focused on major metropolitan areas would be a helpful tool to guide urban adaptation planning, providing a geographically explicit estimation of the probability of multi-hazard economic risks. The city can provide a context for modeling the range of inundation threats by assembling fine-tuned topographical data, mapping public infrastructure and public service assets (schools, hospitals, administrative buildings), and updating socio-economic data. Local ‘vulnerability mapping’ would constitute a bottom-up approach, identifying not only those areas sensitive to current climate conditions but those locations, communities, or ecosystems that are most exposed to projected climate risks.

Among possible adaptive measures:

- Raising dikes, levees, tide gates, and sea walls;
- Raising and reinforcing structures at risk of scour or inundation;
- Relocating roads, water mains, power lines and other infrastructures at higher elevations or further inland;
- Absorbing more rainfall and/or increasing evapotranspiration through urban forestry programmes, green roofs, pervious surfaces, swales and detention ponds;
- Prohibiting development in the most vulnerable areas;
- Creating ‘space for the river’ by opening land for periodic inundation;
- Creating/supporting insurance mechanisms to spread risks and send price signals;

- Implementing ‘soft-grid’ semi-autonomous systems that can survive catastrophic failure of centralized systems.

Land management Water-sensitive land use planning must incorporate water issues in spatial planning and construction standards, especially for new-build areas. Through adjustments to building codes, subdivision standards and infrastructure regulation, the costs of adaptation measures can be spread over long periods. Better management of the recycling of rain-water through vegetation and soil has the potential to reduce flooding, mitigate urban pollution and even offset the urban heat island effect. This may require changes in behavior as well as in urban design. For the broader public, information campaigns and stakeholder involvement will be essential in order to build understanding and support for the necessary land use and property management measures.

Case 1: Mombasa – Merging adaptation and disaster reduction⁴

Mombasa, with 700,000 people, is Kenya’s second largest city. Its harbors serve not only Kenya but also its land-locked neighbors Uganda, Rwanda and Burundi, and parts of the Congo and Tanzania. Mombasa is particularly vulnerable to sea level rise, floods, droughts and strong winds. Dense unplanned settlements have increased flooding in the city because of perimeter walls built along waterways and structures encroaching on areas designated for drains and sewer lines.

In response to the 2004 Asian Tsunami and recurrent coastal flooding, Kenya’s National Government has taken the lead in developing climate change adaptation plans for Mombasa. First steps include gathering climate information, monitoring sea-level rise, early detection of extreme events and implementing disaster response mechanisms. Efforts are underway to create public awareness of climate change risks, share information with vulnerable communities and involve a broad range of governmental, academic and civil society entities. The Government is formulating a coastal zone management policy to regulate development along the coastline and match structural requirements to specific

risks. Degraded coastal areas are being reforested to strengthen the seawall.

A 2007 adaptation study for Mombasa urges the municipal authority to take the following steps:

- Enforce the Physical Planning Act and city by-laws;
- Require construction and maintenance of drainage facilities;
- Repossess public utility land that has been allocated to private developers;
- Ensure that areas demarcated for water, drainage and sanitation are not encroached upon; Bar construction in flood-prone areas; Address the issue of landlessness to enable construction of planned settlements away from the most vulnerable areas;
- Enact building standards that can accommodate future climate conditions;
- Strengthen and enlarge community participation in district-level disaster management committees.

Case 2: Antwerp – Inundation areas and raised dikes⁵

Antwerp is built on the tidal estuary of the Scheldt River and has been protected for centuries by a system of dikes. Mean high-tide levels have been rising, the frequency of storm events has increased, and both will continue to increase with climate change. However, the Belgian Government has determined that construction of a storm surge barrier cannot be economically justified and that merely continuing to raise the height of the dikes is not by itself a sustainable solution.

The proposal is to create inundation areas in the Scheldt estuary beyond the city limits in various configurations to absorb water surges from river or sea. These are costly solutions: people will be displaced, agricultural uses will be lost and the flow of natural watercourses and creeks will be disrupted. Amending local land use plans and constructing these inundation areas appropriately is expected to take 25 years.

⁴ Based on: Awuor et al. (2007).

⁵ Based on: London Climate Change Partnership (2006).

Case 3: Miami – Multi-agency planning⁶

A 2007 OECD report identifies metropolitan Miami, Florida, as the number one most vulnerable city worldwide in terms of dollar-value of assets exposed if a 1-in-100-year surge-induced flood event were to happen today. When considering climate change and sea-level rise, the report lists Miami as one of the top ten cities worldwide for population exposure related to coastal flooding. However, local politics and economics continue to drive investment in vulnerable coastal areas.

Because of America's decentralization of water management, spatial planning and related responsibilities, there is no recognized central authority for climate change risk assessment and adaptation in the Miami metropolitan area. The 2.5 million people in Miami-Dade County are served by 35 cities, various water districts and multiple government entities with environmental or infrastructure portfolios. Thus the climate change adaptation effort must engage each municipality and local governmental entity in assessing the impacts of climate on that entity's own responsibility. Prohibiting or limiting infrastructure and development in coastal or flood-prone areas and coordinating water, drainage and wastewater management to reduce saltwater intrusion will require cooperation from multiple entities. Similarly, new minimum standards for public investment in infrastructure and buildings, which might include raised street grades or building ground-floor elevations, must be coordinated among the 35 cities in the metropolitan area. A multi-stakeholder task force convened by Miami-Dade County has issued preliminary adaptation recommendations and is seeking the voluntary collaboration of all local authorities.

Key questions

How can the gap between knowledge and decision-making be closed? How can climate change be drawn on positively to shape sector development?

Coastal cities and urban areas at risk of inundation are almost always caught in a battle of uncoordinated jurisdictions. In each of the cases above, the risk is

known but implementation is stymied by institutional inertia or complexity. Kenya nationally has analyzed the risks to the city of Mombasa, but city by-laws and enforcement would be necessary to prevent clogging floodways. Making 'room for the river' around Antwerp will require changes in land use that are likely to span several decades. Miami-Dade County has developed knowledge about sea-level rise, but decision-making is in the hands of 35 separate cities and numerous sub-entities.

In most metropolitan areas, spatial planning and water services are handled by separate agencies. The political pressures for land development are frequently beyond the influence of the water and sanitation authorities. However, the high cost of water-related disasters may spur positive adaptation actions. Given the inexorability of sea-level rise, coastal cities (and their national governments) must not only strengthen their disaster preparedness (such as early warning and evacuation programmes for storm events) but also devise ways to manage land development for disaster prevention and to climate-proof water and sanitation services. Innovations are urgently needed – both technical solutions and new institutional arrangements.

General citizen understanding and concurrence will be a pre-condition for implementing many essential adaptation actions, particularly those that require changes in spatial planning and use of the land. Public outreach must be a key component of an Adaptation Agenda.

3 Water scarcity

Climate Impacts and Vulnerability

Cities consume only a small percentage of total global freshwater resources, but the intense local demand they create often drains the surroundings of ready supplies. Climate change and variability introduce new risks for water supply for many cities.

- Cities that rely on winter snowpack may lose that certainty where glaciers are melting or winter precipitation now falls as rain;
- Cities that rely on rainfall may face changes in the seasonality, amount and intensity of precipitation;

⁶ Based on: Miami-Dade County Climate Change Advisory Task Force (2008).

- Cities that rely on groundwater may find that climate changes or competing extractions have altered the reliability of groundwater recharge;
- A direct climate change risk for many cities is the increased intensity, frequency, and geographical extent of drought.
- As coastal cities grow, over-extraction of groundwater together with a rising sea level results in salt-water intrusion and loss of potable water supply;
- Water scarcity in many regions will bring greater demands by users upstream to divert water for agriculture or other community use, leaving downstream cities stranded.
- Private vendors;
- Acquisition of water rights from agriculture;
- Matching use of water to quality (use potable water for potable purposes and use rainwater or on-site recycled water for toilets, irrigation, cooling, etc.).

Decision support tools for water management decision-making in uncertainty are being developed to assist city water utilities in matching portfolio strategies to climate variability. (See e.g. ‘Water Sim’ for Phoenix, Arizona – www.watersim.asu.edu)

Case 1: Seattle USA – Portfolio planning⁷

For a hundred years Seattle has relied on mountain snowpack feeding two large reservoirs as the water source for a city water system that now serves 1.2 million people. With snowpack already declining by 25% as a first result of climate change, Seattle has developed a portfolio of options to ensure the long-term reliability of its water supply. These include:

- Aggressive demand management measures, including tiered tariffs, subsidies for equipment and appliance retrofits, and industrial process water recycling;
- Capital improvements to reduce leaks and operational losses to <5%;
- Maximizing use of its deep-water reservoirs, which requires approval by native tribes and environmental agencies due to biodiversity impacts;
- Negotiating agreements and building interties with adjacent water districts that have a different supply profile;
- Options for groundwater recharge and conjunctive use

Seattle owns and operates its water system, which allows the city significant flexibility. Seattle created strong citizen support for tiered tariffs and other demand management measures with a campaign that focused on the need for environmental flows to preserve Pacific salmon in Seattle’s rivers. The city’s demand-side programmes and internal efficiency measures have already resulted in water savings that stretch the supply reliability out many decades, even in the face of loss of snowpack.

Strategies

Demand management and loss reduction – Water scarcity may be a function of an arid climate or a lack of systems for collecting, storing, allocating and distributing available water. In either case, demand-side measures at the local level will be essential. Many cities in the developed world could reduce water consumption dramatically without reducing quality of life. In the developing world, leakage and unaccounted-for water are as much as 50% of piped water in some urban systems. Addressing water efficiency and water system loss are first steps in adapting for scarcity.

Portfolio planning – City water providers must learn to plan, not for the climate of the past, but for the uncertainty of the future. Urban water service providers will need to engage in portfolio planning – developing parallel strategies and assessing each option in terms of life-cycle costs (including energy footprint) and regulatory and environmental hurdles. An urban water supply portfolio should contain a number of measures that can be implemented and ramped up or down as they prove feasible and cost-effective; for example:

- Building more storage;
- Conjunctive use of surface water and ground water, with ground water recharge;
- Desalination;
- Rainwater harvesting/stormwater harvesting [Singapore];
- Use of recycled water, including industrial process water and treated wastewater;

⁷ Based on Clean Air Partnership (2007) and personal interviews.

Case 2: Zaragoza – Water loss management and water demand management⁸

Zaragoza is a compact city of 650,000 in an arid region of Spain where climate change forecasts indicate deeper drought. Responsibilities for water management are spread over a wide range of city departments with no specific water/sanitation agency. However, the municipal council has established a multi-stakeholder Water Commission which coordinates water management through the Agenda 21 office. As part of the UNESCO/EU SWITCH programme, Zaragoza is a demonstration city for best practices in water loss reduction and demand management.

Water loss reduction involved installation of bulk water meters and telemetry analysis to support rapid detection of system leaks. Pressure management, pipeline and asset management, and other best practices are pilot-tested in one district before being implemented citywide.

The Mayor set a target of reducing domestic water consumption to 90 litres per person per day by 2010. A programme to influence consumer behavior includes information campaigns, price signals (stepped tariffs) and technical assistance. In response to higher water tariffs, an important paper manufacturing firm plans to cut its water use in half by recycling its process water. By hosting the 2008 Expo with a theme of Water and Sustainable Development, Zaragoza is building strong civic pride in sustainable management of limited water resources.

Case 3: London – Leveraging national government action through partnerships⁹

For London, scientists forecast warmer, wetter winters and hotter, drier summers, coupled with an increase in the frequency of extreme weather and rising sea levels, resulting in increasing risk of flooding, drought and heatwaves. With respect to water scarcity, London's position in a region of the UK where relatively little rainfall must be shared by more people, where London's microclimate aggravates the impact of heatwaves, and where anticipated

urban population growth will swell water demand, intensifies the water supply challenges.

However, very few of the measures generally used to reduce urban water demand are within the direct authority of London's municipal government. London does not own or regulate its water service provider. City officials cannot reduce water system leaks. City officials do not have the authority to require that all water services be metered, nor can they set rates to ensure the proper consumer price signals. London cannot require that household appliances or business equipment be rated for water efficiency, nor can it require the water utility to give rebates for water-efficient installations. Not surprisingly, the first innovation needed is not to invent but to apply proven water management measures, including such demand-side measures as metering, pricing, pressure and leakage control, appliance-rating, rebates and efficiency promotions.

London's 2008 Climate Change Adaptation Strategy was developed in a Government-created partnership among the Greater London Authority, Thames Water Utilities, Transport for London, the Association of British Insurers, and Government agencies. All these key stakeholders were engaged in analysis of climate risks and in cost/benefit assessment of adaptive measures. On the strength of this partnership, London's Mayor proposed a drought strategy that begins with actions for reducing water system leakage, a twenty-year programme for compulsory metering of all residences, retrofitting existing London homes for water efficiency and improving water efficiency standards for new construction. Because of the partnership, the Greater London Authority is in a strong leverage position to persuade national authorities and regulators to take the necessary actions to implement the adaptation programme.

Key questions

*How can a portfolio of adaptation measures be designed?
How can adaptation measures be identified and prioritized?*

While many city leaders recognize that climate change will impact water resources, the range of uncertainties makes political action risky. Therefore, in the first instance, climate change should spur local measures to adapt to existing climate variations and to adopt sound water management practices. Identification of 'no-

⁸ Based on: www.switchurbanwater.eu.

⁹ Based on: Greater London Authority (2008), pp 29–40, which also addresses flooding and heatwaves.

regrets' measures for early implementation, followed by training in use of probabilistic decision tools for subsequent action, should be incorporated in the Adaptation Agenda.

What is required to get money to be committed – here, acceptance of higher water rates, tiered tariffs and investment in demand management?

The cases demonstrate that civic engagement is essential to support adaptation for water scarcity, particularly as consumers are required to pay or pay more. London is leveraging a high-level stakeholder process; Seattle used a popular biodiversity campaign; and Zaragoza created a themed 2008 Expo. These kinds of engagement help consumers to understand their responsibility for water, as well as their 'right to water'.

4 Heightened competition for water

Climate Impacts and Vulnerability

In many parts of the world, climate change and variability will result in water insecurity and increased competition for reliable fresh water supplies. However, often cities are not able to make management or investment decisions about the fate and future of their essential water sources. They may have no political mechanism for participating in a decision as to whether water is diverted to agriculture or to another community – even another nation – upstream. City leaders may not have any leverage in resolving trade-offs between urban and agricultural water demands, even though the people of the city must have both food and water. While Integrated Water Resource Management (IWRM) is widely advocated, local authorities seldom are given an organized voice in river basin or transboundary water negotiations.

Most national governments and international organizations have separate bureaucracies to deal with agriculture, urban, environmental, and 'foreign' affairs. Water allocations based on climate patterns, farming practices and urban populations of the past may not be equitable or flexible enough for future conditions. If the national bureaucracies are not working together, competition for water resources

may be exacerbated. Again, city officials are often powerless in these matters.

The way a city seeks to adapt to climate change can have adverse externalities on the environment and other water users. Buying up agricultural water rights may have negative impacts for rural workers or may affect food prices. New urban water works may alter environmental flows in rivers and may threaten biodiversity or fisheries. Piped drainage systems may cause deterioration of ecosystem services such as the filtration potential of wetlands.

It must be noted that heightened competition for water may be internal to the city, with the rich getting piped city water and the poor having to pay more for water from private vendors. The social and economic tensions within the city are particularly compelling challenges for local politicians.

Strategies

IWRM participation – One set of strategies gives cities a voice in river basin water allocations or IWRM processes. South Africa, for example, has been very active in bringing local governments into catchment management processes. At the very least, city officials and key water decision-makers must develop a mutual understanding of the constraints and possibilities in the system. ICLEI provides IWRM training for local authorities in Africa.¹⁰

Economic instruments – Market-based mechanisms may be created allowing cities to buy water rights from irrigators, for example, by paying for irrigation efficiency improvements. Water transfers, aquifer recharge or conjunctive use agreements may be negotiated. Economic instruments, such as the option contracts for urban agriculture trade-offs in low water years used in California, may allow fuller use of shared resources under variable conditions.

Closed-loop sustainability – Another set of strategies seeks to make a city largely internally sustainable. Water demand is reduced through leakage control, industrial process water reuse and consumer efficiencies. Rainwater is harvested and stormwater is infiltrated to recharge groundwater or is captured for urban use. Grey water is recycled and treated waste-

¹⁰ Based on: ICLEI (2008).

water is reused. Ground water and surface water sources are used conjunctively with a view to sustainability of the resource. A sub-district within a city may be designed with sustainable, 'closed loop' water services to reduce the intra-city competition for water resources.

Case 1: Melbourne – Purchasing water efficiency savings from agriculture

Faced with critical water shortages, Australia has set up a mechanism for the City of Melbourne to actively participate in trade-offs with the agricultural community of the Murray-Darling Basin. The scheme aims for efficient sharing and optimizing of the water resource between irrigators and urban users, with fifty percent of the water saved being reserved for the environment. A cap on water withdrawals from the Basin will be administered in the context of the mega-relationship of agriculture, urban areas and environmental flows.

The plan requires significant government investment. National Government dollars will

- support irrigation infrastructure modernization;
- compensate farmers for water rights lost under the new cap;
- buy back water rights from willing sellers;
- help build a pipeline to transport water from efficiency savings to Melbourne.

The agreement allows Murray-Darling Basin water resources, including groundwater, to be managed conjunctively.

Case 2: Alexandria – Nested 'closed loop' developments¹¹

At the mouth of the Nile River, the city of Alexandria faces the challenge of increased competition for river resources from the 10 nations and many cities and farm communities that use the river waters upstream. With 4 million people and an extra 2 million annual holiday visitors, Alexandria relies primarily on the Nile as its urban water source. Alexandria is engaged in a long-range strategic planning process, as part of the UNESCO/EU SWITCH programme, to develop Integrated Urban Water

Management (IUWM). A key driver of the process is the city's vulnerability to competing demands on the Nile waters upstream, which are likely to increase under predicted climate change scenarios.

Alexandria is assessing a full range of strategies for diversifying its water supply and usage – rainfall harvesting, water demand management through water-sensitive design, reuse of treated wastewater, gray water recycling, desalination of sea water and brackish groundwater, and decentralization of wastewater treatment. The goal is to develop a set of feasible options for sustainable water supply that does not rely solely on the Nile.

One strategy under consideration is the development of closed-loop systems for sustainable neighborhood-scale IUWM. A demonstration project is proposed for an underserved peri-urban area – a fishing village of 10,000 on the shores of Lake Maryut. This is a slum area without adequate sanitary services. The project involves piloting of the most appropriate technologies for retrofitting a dense, built-out community, including water sensitive design, metering and water demand management, decentralized wastewater treatment, rainwater harvesting and wastewater reuse. The goal is to minimize water use, upgrade basic infrastructure, protect Lake Maryut from pollution, improve aesthetics and public health, and strengthen regulatory systems. Key programme indicators are social inclusion, gender equity and pro-poor measures. Institutional and governance systems will be assessed, along with operational feasibility and financial viability. It is hoped that lessons learned from the demonstration can be applied in other neighborhoods to result in a water plan less vulnerable to competing demands for the waters of the Nile.

Key Question

How can climate change be drawn on to positively shape water sector development?

Heightened competition for water resources is driving innovation, particularly where local authorities are responsible for supplying water to urban populations. Australia has implemented new economic arrangements to balance urban, agricultural and environmental water use in the Murray-Darling Basin. Alexandria is considering a neighborhood-

¹¹ Based on: www.switchurbanwater.eu.

scale Integrated Urban Water Management to make a village of 10,000 self-sufficient. Eight cities from four nations along the Limpopo River have worked together to provide a template on IWRM planning.¹²

5 Pollution

Climate Impacts and Vulnerability

In the best of systems, concentrated human settlements together with concentrated industrial enterprises create serious risks of water contamination. Climate change brings hydrological variability and catastrophic weather-related events that are likely to overwhelm even well-engineered systems for treating and disposing of urban wastes. Industrial wastes and other pollutants, even if properly disposed of, may be released by extreme storm events. In informal settlements where basic services of waste management and drainage are not provided, storms and flooding cause additional risks to health and livelihoods.

Most conventional human waste disposal systems are vulnerable to high water tables and inundation. Flooding often damages pit latrines (relied on by much of urban Africa and Asia), and is usually contaminated by overflow from septic drain fields and often sewers. Sewer systems fill with water in storm events through inflow and infiltration (I & I), resulting in pollution from CSOs (combined sewer overflows). Toilets linked to flooded sewers become inoperable.

Additional threats to water quality are likely where climate change results in:

- Water temperatures that exceed operational parameters;
- Invasive species;
- Turbidity from landslides and erosion due to extreme events;
- Low flows in rivers or water bodies due to drought.

Water-borne contamination, whether from industrial, agricultural or human waste, spreads downstream. Coordinating water quality standards and targeting preventive investments becomes essential in the face of climate uncertainties.

Strategies

Looking forward, cities need to design and build appropriate, robust sanitation, solid waste and industrial waste solutions that can functionally withstand dramatic weather variations. Areas of potential pollution and contamination release need to be defined so that protective measures can be developed. Possible measures include:

- Sewage treatment plants at higher elevations or with protective levees;
- Decentralized closed-loop wastewater treatment;
- Waterless or low-water waste disposal;
- Separate storm and sewer drains to reduce CSOs; I• nflow and infiltration control;
- ‘Polluter pays’ strategies.

Non-conventional wastewater treatment – An array of decentralized alternatives for treating human waste on-site and reusing the liquid and solid outputs are becoming economically feasible and safe for human and environmental health. These include, for example, Clivus Multrum self-composting toilets, STEG/STEP septic systems, vacuum systems and membrane bioreactors. Some of these alternatives are fully enclosed and not affected by I&I or high water conditions, so are less vulnerable to the spread of pollution as a result of flooding. However, there may be regulatory hurdles to implementing non-conventional systems in the developed world. In developing countries, systems that need reliable electricity may not be practicable.

Case 1: Great Lakes and Lake Victoria – Trans-boundary collaboration of cities for pollution control¹³

The Great Lakes shared by Canada and the United States in mid-Continent are threatened by pollution from decades of industrial, agricultural and human waste. Climate change escalates the threat to the resource, especially as intensified storms overwhelm wastewater and drainage systems built to standards of the last century. The Great Lakes and St. Lawrence Cities Initiative was launched by Chicago Mayor, Richard Daley, and Toronto Mayor, David Miller, to provide local government action for solutions. The

¹² Based on: ICLEI (2008).

¹³ Based on: www.glslicities.org.

mayors recognized the value of shared efforts to clean up past degradation and restore ecological values. They called for uniform water quality standards on both sides of the transboundary waters.

The Great Lakes Cities Initiative has documented that the 688 local governments that rim the Great Lakes invest an estimated \$12 billion annually for water quality management and \$3 billion for ecosystem protection. Measures include upgrading wastewater treatment facilities, restoring beaches and preserving biodiversity. The Great Lakes Cities Initiative enables cities to bring a united voice to their national governments in demanding financial support for the infrastructure investments needed to protect water quality in the lakes whose shores they share.

A similar initiative in Africa is the Lake Victoria Regional Local Authorities Cooperation. Launched by Entebbe's Mayor Stephen Kabuye and others, the pact provides regional standards for protection of water quality and water resources.

Case 2: Boston – Infrastructure elevation assumes sea-level rise¹⁴

A study of climate change impacts to critical infrastructure in the Boston Metropolitan Area identified sea-level rise as one of the primary threats. Boston's new sewage treatment plant, built in 1998 by the Massachusetts Water Resource Authority, is located on an island in Boston Harbor. Untreated sewage is pumped from the city under the harbor and up to the plant for treatment. Prior to construction, the Authority assessed likely sea-level rise and storm surges. They compared the life cycle costs of building the treatment plant at a higher location, which entails extra intake pumping, with building at a lower location which would subsequently require the construction of a protective wall around the plant and additional pumping to carry the treated effluent over the wall for discharge into the harbor. The higher location proved to be the better long-term investment and, additionally, has enhanced the resilience of the system to current storm surges.

¹⁴ Based on: Clean Air Partnership (2007) and Kirshen et al. (2004).

Key questions

How can climate change be drawn on to positively shape sector development?

The public health achievements of the developed world in the twentieth century arise, in large part, out of the sanitary infrastructure constructed in urban areas, engineered for a 50-100-year service life and to high human health standards. Climate change and extremely rapid urbanization render some of the past solutions inadequate – wasteful of water and energy – and require innovative strategies.

New systems are being developed, many of them on-site or decentralized, but social acceptance, regulatory modifications and then scaling-up will all take time. The decentralized treatment systems have the added advantage of reducing demand on conventional infrastructure, in many cases better-protecting ecological functions, often consuming less water, energy and concrete, creating resilience in the broader system and avoiding costs.

What is required to get money to be committed?

Resilience strategies may be justified by avoided costs. Reducing water consumption avoids the costs of enlarging water supply infrastructure and building new storage. Controlling I&I avoids the cost of larger sewer pipes and treatment plants. On-site waste treatment avoids both I&I and the cost of sewer mains enlargement and CSO controls. However, avoided costs don't necessarily equate to money in the municipal till. To the extent infrastructure is financed by national or other grants, it may be easier for a city to secure funds for new or larger systems than for implementing the strategies that reduce or defer demands on the existing infrastructure. The Adaptation Agenda should address this challenge.

6 Other Vulnerabilities – Biodiversity and Human Health

Other water-related risks to urban areas are beyond the scope of this paper. Each city will need to assess and plan for additional possible climate effects such as:

- Altered distribution of water-related diseases;

- Loss of aquatic biodiversity and associated resource-based livelihoods;
- Heat waves and exacerbated urban heat island effect;
- Algal blooms and water quality problems resulting from new temperature regimes;
- Deterioration of environmental services from degradation of coastal and riparian areas and loss of wetlands.

Conclusion – Political principles and local government adaptation

Essentials for the Adaptation Agenda – Particularly where water service responsibilities are decentralized, the Adaptation Agenda must include down-scaling the climate predictive models to the local level and providing financial and technical resources for local impact assessments. The Agenda must ensure support for the institutions that will enable the local government to implement the indicated adaptations, whether financial mechanisms, land use frameworks or IWRM participation.

In developing countries, the Adaptation Agenda must start by recognizing the deficit in urban infrastructure for sound water services and water-disaster prevention. Water, sewer and drainage systems, as well as flood/storm defenses must be designed and built, in the first instance, to withstand anticipated climate patterns.

Other components of the Adaptation Agenda are indicated by application of the political principles summarized below.

Climate change in context – Climate change is a major driver of water-sector change in the cities of the world, but rapid urbanization and economic globalization are equally important. Mayors and city leaders must respond to a myriad of demands, and long-term water-system challenges aren't always high on the political priority list. Furthermore, the uncertainty about future climate patterns makes political action difficult. However, because climate change will directly impact core functions of most of the world's large cities, the water sector must find ways to engage mayors proactively.

Climate-proofing the MDGs – Climate change/variability directly threatens progress on

achieving the MDGs, particularly the goals for water and sanitation, as the urbanizing world is increasingly at risk of water-related disasters, from drought to inundation. In the developing world, likely climate shifts must be mainstreamed into city plans for water infrastructure, land development and sanitation systems, as the Mombasa, Durban, and Alexandria cases demonstrate.

Climate change and water sector adaptation – Implementing IWRM and sustainable land use management are of course essential. However, in most nations there is not a clear path for IWRM involvement and buy-in by city officials. Furthermore, the political will and authority for sustainable land use measures may be divided among various authorities or levels of government and, at any level, is subject to competing economic demands. *Too many construction permits are still given in zones at risk.* This is perhaps the most intractable obstacle to climate change adaptation for urban areas.

Water/energy nexus – Policy decisions require consideration of water footprints of energy and energy footprints for water. Mayors have been leaders globally in implementing climate change *mitigation* strategies, focusing on energy efficiency and greenhouse gas reductions, through ICLEI's Cities for Climate Change, the World Mayors' Council on Climate Change, and the C40 Cities Climate Leadership Group, for example. Mayors are now beginning to address climate change *adaptation*, which directly involves city leaders in water sector measures. Still, integrating consideration of water and energy in crafting adaptation measures will be difficult at local level because these services are typically provided by different agencies with different political drivers. The Adaptation Agenda should promote an integrated approach to climate mitigation and adaptation.

Climate-proofing infrastructure and development – More hydropower, inland navigation, groundwater use and increased storage are important adaptation considerations. This paper suggests that localized climate projections and vulnerability assessment are essential first steps in water sector adaptation planning for any metropolitan area and will lay the groundwork for consideration of specific adaptation measures.

Capacity-building – City leaders have identified the necessity for capacity-building in adaptive management or cyclic management. Local governments need training and support in scenario-building, modeling of uncertainties and use of probabilistic decision tools. Collaboration with researchers and inclusion in knowledge networks is increasingly important. In countries where water responsibilities are being decentralized, capacity-building will necessitate legal, financial and institutional adjustments as well.

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