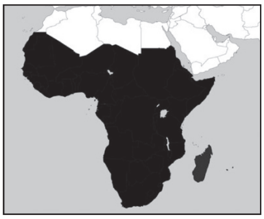

Testing a rapid climate change adaptation assessment for water and sanitation providers in informal settlements in three cities in sub-Saharan Africa

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ABSTRACT Climate change is expected to affect the poor in low- and middle-income countries most, particularly in the next few decades, through increased flooding and droughts. A very large number of these poor live in informal urban settlements, where they rely on water kiosks and pit latrines and where there is usually inadequate provision for drainage. Despite an abundance of publications on climate change, there is little advice that is specific to those providing water and sanitation services to the urban poor in these countries. This paper presents a Rapid Climate Adaptation Assessment (RCAA) for water and sanitation providers that generates recommendations on climate proofing for local service providers, utilities and local governments. Overall, the RCAA converts regional climate predictions into recommendations for local adaptations. The methodology was developed through fieldwork with communities in Lusaka (Zambia), Naivasha (Kenya) and Antananarivo (Madagascar). The paper describes the methodology, summarizes the results of its application (and the implications for adaptation) and discusses its wider application and limitations. In most cases, the proposed adaptations are not new actions, and could be described as "good water management".

KEYWORDS climate change adaptation / climate change impacts / informal settlements / sanitation / water

I. INTRODUCTION

There is a wide range of uncertainties associated with predictions of anthropogenic climate change;[1] however, the scientific community now widely accepts that it is a reality.[2] Water is one of the primary media through which climate change will influence the Earth's ecosystems[3] and people's livelihoods.[4] Changes in rainfall patterns, amounts and intensity will increase the risk of flooding and droughts[5] and exacerbate current stresses on water resources. Africa is the continent most vulnerable to climate change[6] and the poor are more vulnerable to climate change than the population as a whole.[7] The majority of these poor live in ecologically fragile zones, and are heavily dependent on natural resources and sectors that are vulnerable to climate variability; for example, one-third of the

African population lives in drought-prone areas.[8] The Stern Report[9] predicted that by 2100, 145–220 million additional people in South Asia and sub-Saharan Africa could fall below the US$ 2 a day poverty line, and every year an additional 165,000–250,000 children could die compared to a world without climate change.

In Africa, climate change impacts will be compounded by population growth,[10] and the damage to livelihoods and resources is widely expected to increase migration into the cities,[11] although this is disputed by Potts.[12]

Since 1990, the urban population of sub-Saharan Africa has more than doubled, yet the proportion of people without access to improved drinking water sources (17 per cent) and sanitation facilities (57 per cent) has remained constant.[13] The poor who lack access often live on marginal land in flood-prone areas.[14] Where safe and legal water supplies do exist, these are often provided by water kiosks, which, in turn, are supplied by the main water utility or a local source. The kiosks can be operated by a local service provider and have independent management, but are supported and regulated through the city's main utility. Water kiosks are still a compromise compared to household connections, as water still needs to be carried to and stored in the home, and this has its own time penalties and water safety risks for the families involved. However, household connections require more complicated legal and financial arrangements,[15] which are undesirable to water utilities. The "local service providers" who operate the kiosks are better able to cope with the informal nature of peri-urban and informal areas although they are limited by lack of finance and technical capacity. Similarly, the urban poor are rarely connected to the sewage network and so are forced to use on-site sanitation such as pit latrines. Depending on national and local regulations, this may fall under the responsibility of the utility or the municipality, or it may fall between them and rely on the informal sector. Again, there is limited finance and technical capacity.

Climate change will severely impact these service providers, and current water management and sanitation practices may not be robust enough to cope with the impacts.[16] Sub-Saharan African utilities' adaptations have mostly been ad hoc, only addressing short-term concerns, and have yet to address climate vulnerability more systematically.[17] Many practitioners argue that it is not yet possible for water managers in low- and middle-income countries to take climate change into account[18] because they are struggling to cope with day-to-day management. However, adapting to present climate variability (increasing resilience, reducing vulnerability) is already an integral part of water management – the efficiency and success depends upon the utilities' governance[19] – and longer-term adaptation can build on this.

There are efforts underway at many levels of government, and within international institutions, to initiate adaptation to climate change,[20] especially in the water resources sector.[21] However, a thorough vulnerability analysis and impact assessment to enable appropriate design and implementation of adaptation measures is lacking in almost all low- and middle-income countries.[22] There needs to be a shift from generic global impact assessments to more locally focused adaptation and response mechanisms,[23] and adaptations need to focus on increasing the resilience of water providers to climate variability.[24] Adaptation policies work best when climate change initiatives link adaptation and development and address the structural conditions that cause vulnerability.[25] It also

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1. UNWATER (2009), *The United Nations World Water Development Report 3. Chapter 5 Climate Change and Possible Futures*, WWDR 021609.indd 68, UNESCO World Water Assessment Programme, UNWATER, accessed June 2010 at www.unwater.org/downloads/15_WWDR3_ch_5.pdf.

2. Royal Society (2010), "Climate change: a summary of the science", accessed October 2010 at royalsociety.org/climate-change-summary-of-science/.

3. UNESCO–WWAP (2009), "Climate change and water: an overview from the *World Water Development Report 3: Water in a Changing World*", a World Water Assessment Programme Special Report SC-2010/WS/5, accessed October 2010 at unesdoc.unesco.org/images/0018/001863/186318e.pdf.

4. UNWATER (2010), "Climate change adaptation: the pivotal role of water", Policy Brief, accessed October 2010 at www.unwater.org/downloads/unw_ccpol_web.pdf.

5. Hadley Centre (2005), "Stabilizing climate to avoid dangerous climate change – a summary of relevant research at the Hadley Centre", accessed October 2010 at www.metoffice.gov.uk/research/hadleycentre/pubs/brochures/2005/CLIMATE_CHANGE_JOURNAL_150.Pdf; also Laukkonen, J, P K Blanco, J Lenhart, M Keiner, B Cavric and C Kinuthia-Njenga (2009), "Combining climate change adaptation and mitigation measures at the local level", *Habitat International* Vol 33, No 3, pages 287–292; and Parry,

needs to be recognized that future long-term changes can introduce new unexpected risks to projects.[26]

So far there has been little focus on water supply and sanitation for the urban poor. The most relevant studies are the DfID WHO Vision 2030[27] review, the CRiSTAL[28] methodology and the USAID methodologies.[29] Vision 2030 gives a comprehensive overview of the resilience of water and sanitation technologies but lacks information on replication or assessing vulnerability. The other methodologies overview community vulnerability and adaptation but lack a water or sanitation focus. To fill the gap, this paper presents a Rapid Climate Adaptation Assessment (RCAA), developed specifically for water and sanitation supply for the urban poor. The RCAA assesses how changes to climate interact with existing vulnerabilities in peri-urban and informal areas, and then recommends adaptations to the existing plans of water providers to increase their climate resilience.

II. METHOD

The RCAA was developed in Lusaka, Zambia, then trialled in two other case study cities: Naivasha, in Kenya and Antananarivo, in Madagascar. These cities were selected because they are part of the international programme of Water and Sanitation for the Urban Poor (WSUP), a tri-sector partnership between the private sector, civil society and academia focused on addressing the increasing global problem of inadequate access to water and sanitation for the urban poor.

The RCAA consists of five stages, which are discussed in turn:

- a literature review, to identify the impacts of climate change;
- fieldwork, to assess the existing vulnerabilities of communities and water providers;
- preparation of hydrological scenarios;
- assessment of the impact of these scenarios on the community; and
- identification, selection and recommendation of adaptations for climate proofing water and sanitation services. The research also allowed an opportunity to assess the overall awareness of climate change among the different stakeholders, as well as their current plans for adaptation.

a. Literature review

A literature review was undertaken first for each city using key climate change resources. Sources such as those outlined in Table 1 are likely to be available for most localities; country-specific resources were used where they were available. The purpose was to identify the likely changes to climate and the resulting impacts upon water resources, health, livelihoods and biodiversity, as these changes will all impact the population's access to water and sanitation services.

b. Fieldwork – vulnerability assessment

Semi-structured interviews, community focus groups and direct observation were undertaken during two weeks of fieldwork in each

M, C Osvaldo, J Palutikof, P van der Linden and C Hanson (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge and New York, 986 pages.

6. See reference 5, Parry et al. (2007).

7. Africa Partnership Forum (2008), "Climate challenges to Africa: a call for action", [cited 15 March 2009], accessed October 2010 at www.africapartnershipforum.org; also World Bank (2009a), *World Development Report 2010: Development in Changing Climate: Concept Note*, [cited 16 April 2009], accessed October 2010 at www.worldbank.org; Nyong, A (2009), "Climate change impacts in the developing world: implications for sustainable development", in L Brainard, A Jones, N Purvis (editors), *Climate Change and Global Poverty: A Billion Lives in the Balance?*, Brookings Institution Press, Washington DC, pages 43–64; and see reference 5, Parry et al. (2007).

8. Hope Sr, K R (2009), "Climate change and poverty in Africa", *International Journal of Sustainable Development and World Ecology* Vol 16, No 6, pages 451–461.

9. Stern, N (2006), *Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge, 712 pages.

10. Carter, R C and A H Parker (2009), "Climate change, population trends and groundwater in Africa", *Hydrological Sciences (Journal des Sciences Hydrologiques)* Vol 54, No 4, Special Issue: "Groundwater and climate in Africa", pages 676–689.

11. Barrios, S, L Bertinelli and E Strobl (2006), "Climatic change and rural–urban migration: the case of sub-Saharan Africa", *Journal of Urban Economics* Vol 60, No 3, pages 357–371.

12. Potts, D (2009), "The slowing of sub-Saharan Africa's urbanization: evidence and implications for urban livelihoods", *Environment and*

TABLE 1
Key resources for literature review available to any low-income country

Documents	Description	Key sections
National Adaption Programme for Action (NAPA)[(1)]	• Details the urgent and immediate needs and concerns of low- and middle-income countries relating to adaptation to the adverse effects of climate change	• Section 2: Framework for the Adaptation Programme • Appendix: Proposed Adaptations
National communications to United Nations Convention on Climate Change[(2)]	• Details the results of national assessments of greenhouse gas emissions as well as information on vulnerability, impacts and adaptation • Observed and anticipated trends and impacts of climate change for each country can be drawn from these documents	• Chapter 1: National Circumstances • Chapter 4: Vulnerability and Adaptation Assessment
UNDP climate change country profiles[(3)]	• Country level studies of climate observations and multi-model projections for 52 countries	• General climate • Recent climate trends GCM • Projections of future climate • Other regional climate change information • Data summary

SOURCE: [(1)] UNFCCC-submitted NAPA, accessed October 2010 at unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php.

[(2)] UNFCCC-submitted non-annex nation communications, accessed October 2010 at unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php.

[(3)] UNDP climate change country profiles, accessed October 2010 at country-profiles.geog.ox.ac.uk/.

TABLE 2
Number of interviews with each stakeholder for the three case studies

Stakeholder	Lusaka	Naivasha	Antananarivo
Community individuals	10	10	2
Community focus groups	1	2	8
Local service providers	12	2	2
Utility	2	2	1
Municipality	3	2	2
Government	8	7	4
Researchers	2	1	–
NGOs	3	3	7
Consultants	–	–	2
Local business	–	2	2

of the cities. The initial interviews were arranged with representatives of the local water and sanitation service providers, the water utility, meteorological organization and municipality, and with researchers identified in the literature review. During these interviews, stakeholders were asked to name other stakeholders who might provide useful insights; these included representatives from regional government, the scientific community and NGOs. The total numbers interviewed are detailed in Table 2.

Urbanization Vol 21, No 1, April, pages 253–259.

13. WHO and UNICEF Joint Monitoring Programme for Water Supply and Sanitation: Data and Estimates, accessed January 2012 at http://www.wssinfo.org/data-estimates/graphs/.

The questions varied with regard to the level of technical detail and the topics covered, depending on the stakeholders' roles. A priority was to clarify the local causes and impacts of floods and droughts, the adaptations required and any existing development plans. The topics discussed included:

- the interviewees' understanding of climate change, its impacts and adaptation;
- the interviewees' understanding of the predicted changes for their locality;
- the impacts of changes in temperature, mean hydrological parameters (e.g. amount or intensity of rainfall) and extreme hydrological events (e.g. floods, droughts) on the water and sanitation technologies and services for these communities;
- the impacts of climate change not directly related to water and sanitation;
- current water resources, including abstractions, discharges and management, and whether the current level of abstraction is sustainable;
- the current procedures and future plans of the water providers; and
- how the community and local service providers adapt during current extreme events.

Community focus groups were organized with 8–16 people (the aim was for 8–10, but more attended), using a translator. The groups were asked to discuss floods first (where they occurred), then droughts (where they occurred), and then the events prior to and during past floods (or droughts). This included questions on when the last event took place, how often the events occurred, how much warning there was, event duration and whether there had been any noticeable changes in their frequency or nature. The impact on the community was then discussed, including livelihoods, education, water supply, sanitation, health, buildings, women, food prices, fuel prices and the community as a whole. The focus groups were then asked to identify the biggest problem, following which, adaptation was discussed, debating the best ways to adapt, reviewing who is responsible and the perceived role of local government, CBOs and NGOs.

Direct observation was used to verify the responses in interviews and focus groups. This included general surveillance of hygiene practices, drainage and buildings, for example checking the quality of drainage channels, construction of latrines, hygiene standards and looking for water marks and other indicators of flooding.

c. Development of hydrological scenarios

Rarely are there hydrological models that can easily show how predicted climate changes would impact the local hydrology of the areas under consideration, and developing them in a rapid assessment would be impractical due to the cost, lack of data and the time required. Simple conceptual hydrological models for each city were therefore developed based on the field data, and a small number of key scenarios were then tested based on the climate change predictions for the region. These scenarios show qualitatively the potential effects on any rivers, lakes and groundwater and runoff levels. For example, in Antananarivo runoff

14. See reference 1, UNWATER (2009).

15. WSUP (2011), "Helping people connect to water networks: good for business, good for the poor?" Practice Note 7, accessed January 2012 at http://www.wsup.com/sharing/documents/PN007HelpingConnectToWaterNetworks.pdf.

16. Bates, B, Z Kundzewicz, S Wu and J Palutikof (editors) (2008), "Climate change and water: IPCC technical paper VI", IPCC Secretariat, Geneva, accessed October 2010 at www.ipcc.ch/publications_and_data/publications_and_data_technical_papers.shtml.

17. Danilenko, A, E Dickson and M Jacobsen (2010), "Climate change and urban water utilities: challenges and opportunities", *Water Working Notes* No 24, Water Sector Board, Sustainable Development Network, World Bank, Washington DC, accessed October 2010 at www.wsp.org/wsp/sites/wsp.org/files/publications/climate_change_urban_water_challenges.pdf.

18. See reference 5, Laukkonen et al. (2009).

19. Batchelor, C, T Schouten, S Smits, P Moriarty and J Butterworth (2009), "Climate change and WASH services delivery – is improved WASH governance the key to effective mitigation and adaptation? Perspectives on water and climate change adaptation", IRC International Water and Sanitation Centre, World Water Council, accessed October 2010 at www.wsscc.org/resources/resource-publications/climate-change-and-wash-services-delivery-%E2%80%93-improved-wash-governance?rck=94d467d83a49eab7df3e7ba6e6cec619.

20. The Heinz Centre (2006), "A survey of climate change adaptation planning", The H John Heinz Centre for Science, Economics and the Environment, Washington DC, accessed October 2010 at www.heinzctr.org/publications/PDF/Adaptation_Report_October_10_2007.pdf.

21. See reference 19, Batchelor et al. (2009).

is already high, which indicates the infiltration capacity is frequently exceeded; therefore future increases in rainfall intensity are likely to further increase runoff.

This analysis was used to assess whether there was a local risk from any of the following:

- increased flooding;
- increased groundwater recharge and a rise in groundwater levels;
- increased runoff with more erosion;
- decreased surface water availability; and
- decreased groundwater levels.

d. Impact assessment

The effects of these hydrological scenarios on existing vulnerabilities in water and sanitation were first reviewed qualitatively using Vision 2030 reports. For example, Vision 2030 identified that a borehole may be vulnerable to increased groundwater contamination from lateral flow in the soil or inundation of the well as a result of an increased risk of flooding, and then lists the possible adaptations. Then the impacts not directly related to water and sanitation, such as changes in food prices, electricity prices or employment, were assessed. Finally, the existing plans were analyzed in order to identify new risks, those areas lacking resilience and aspects of the plans that could be vulnerable.

e. Climate proofing

Finally, a set of recommended adaptations was developed for service providers. Suggested adaptations from the focus groups and interviews were reviewed together with the adaptations recommended for the specific technologies from Vision 2030. Adaptations were sought that improved the systems' current resilience to climate variability, that were appropriate to the service providers and addressed actual risks. Adaptations were made specific to the local service provider, water utility or municipality and were sub-divided according to timescale(30) and between the following categories:(31)

- capital expenditure;
- operational expenditure;
- monitoring; and
- socioeconomic.

III. RESULTS FROM THE CASE STUDIES

This section summarizes the findings and recommendations resulting from the three case studies in Lusaka, Naivasha and Antananarivo. For more details, the comprehensive country reports can be downloaded.(32)

a. Lusaka – Zambia

Background: Despite having 40 per cent of Southern Africa's water resources,(33) Zambia experiences water scarcity. This is due to a

22. Nath, P K and B Behera (2010), "A critical review of impact of and adaptation to climate change in developed and developing economies", *Environment, Development and Sustainability* Vol 13, No 1, pages 141–162.

23. See reference 19, Batchelor et al. (2009).

24. Muller, M (2007), "Adapting to climate change: water management for urban resilience", *Environment and Urbanization* Vol 19, No 1, April, pages 99–113.

25. Sanchez-Rodriguez, R (2009), "Learning to adapt to climate change in urban areas. A review", *Current Opinion in Environmental Sustainability* Vol 1, pages 201–206; also Simon, D (2010), "The challenges of global environmental change for urban Africa", UNU–Wider Working Paper 51, accessed August 2010 at www.wider.unu.edu/publications/working-papers/2010/en_GB/wp2010-51/.

26. USAID (2007), "Adapting to climate variability and change; a guidance manual for development planning", accessed October 2010 at www.usaid.gov/our_work/environment/climate/docs/reports/cc_vamanual.pdf.

27. Howard, G, K Charles, K Pond, K Brookshaw, R Hossain and J Bartram (2010), "Securing 2020 vision for 2030: climate change and ensuring resilience in water and sanitation services", *Journal of Water and Climate Change* Vol 1, pages 12–16.

28. IISD (2009), "CRiSTAL: Community-based Risk Screening Tool – Adaptation and Livelihoods", International Institute for Sustainable Development, Stockholm Environment Institute, Intercooperation: Swiss Foundation for Development and International Cooperation, International Union for Conservation of Nature, accessed June 2010 at www.cristaltool.org/.

29. See reference 26, USAID (2007).

combination of seasonal and temporal rainfall patterns and limited investment in infrastructure. The fieldwork focused on two peri-urban areas in Lusaka, namely Chazanga and Kanyama. Chazanga is a hilly area located north of the city centre and had a population of 35,000 in 2007. Kanyama is located southeast of the city and had a population of 198,000 in 2007. Kanyama is very flat and rocky and is the natural drainage plain for the city; as a result it experiences severe flooding. Water is supplied to both areas by community cooperatives (water trusts), using boreholes and kiosks that are licensed by the city's main water utility through a Memorandum of Understanding. The community also uses shallow wells for water, which should be for non-consumptive use; however, some families do use it as drinking water if they cannot afford or do not want to use kiosk water. Sanitation facilities comprise pit latrines, although there are some ecosan programmes and also some efforts to elevate latrines.

Climate change: The main risks from climate change facing Zambia are an expected increase in floods and droughts combined with a reduction in *miombo* woodland and maize yields.[34] The mean temperature is predicted to increase, with a greater frequency of "hot" days and nights and very few "cold" days or nights. Total rainfall and rainfall intensity are expected to increase in summer and the frequency and intensity of extreme events, principally droughts and floods, are expected to increase.

Hydrological scenarios: Two scenarios were developed for Lusaka based around precipitation changes. Increased precipitation would likely increase the level of the main river (Kafue) and of groundwater and also the intensity of localized flooding. Decreased precipitation would likely lower the groundwater level – the majority of interviewees believed that current groundwater abstractions were greater than recharge and hence were already unsustainable.

Vulnerabilities and impacts: Chazanga is most vulnerable to a decrease in rainfall and a lower water table, increasing the likelihood of water scarcity, damage to water kiosks and pipes and drying up of shallow wells, all of which will increase the demand for new kiosks. Decreased rainfall could also affect hydroelectric generation, causing power shortages. However, if rainfall or rainfall intensity do increase, flash floods are likely to damage boreholes, kiosks, septic tanks and pit latrines, and the poor drainage at kiosks would be exacerbated. Lastly, there is likely to be an increase in climate-driven migrations to the area, increasing pressure on land and exacerbating the problems associated with the limited latrine-emptying options.

In contrast, Kanyama is most vulnerable to an increase in rainfall, resulting in an increase in flooding; the 2009–2010 flood lasted for three months. Flooding causes kiosks and buildings to collapse, contaminates water supplies (particularly the shallow wells used in the areas unserved by the kiosks) and affects livelihoods, education and health. Flooded latrines and contaminated water increase the risk of cholera and diarrhoea. A decrease in rainfall could be beneficial for Kanyama, reducing the likelihood of flooding.

Climate proofing: In Chazanga, water shortages due to power failures could be mitigated by acquiring a generator; in the longer term, the Chazanga Water Trust needs to investigate alternative sources of water and/or deepen their boreholes. To protect infrastructure from heavy rainfall, the soil needs to be stabilized with buffer strips and erosion control measures, and drainage standards for soakaways need to be

30. Venton, P, J Cacouris and C Cabot (2010), "How to integrate climate change adaptation into national level policy and planning in the water sector: a practical guide for developing country governments", Tearfund, accessed October 2010 at tilz.tearfund.org/webdocs/Tilz/Topics/watsan/Water%20Adaptation%20Guide_Web.pdf

31. Charles, K, K Pond and S Pedley (2010), "Vision 2030: the resilience of water supply and sanitation in the face of climate change", Technology Fact Sheets, University of Surrey, accessed October 2010 at www.who.int/water_sanitation_health/publications/vision_2030_technology_fact_sheets.pdf.

32. Heath, T, A Parker and E Weatherhead (2010a), "How to climate proof water and sanitation services in the peri-urban areas in Lusaka", WSUP, Cranfield University, London, accessed October 2010 at www.wsup.com/sharing/Resources.htm; also Heath, T, A Parker and E Weatherhead (2010b), "How to climate proof water and sanitation services in the peri-urban areas in Naivasha", WSUP, Cranfield University, London, accessed October 2010 at www.wsup.com/sharing/Resources.htm; and Heath, T, A Parker and E Weatherhead (2010c), "How to climate proof water and sanitation services in the informal areas and peri-urban areas in Antananarivo", WSUP, Cranfield University, London, accessed October 2010 at www.wsup.com/sharing/Resources.htm.

33. Zambia: National Adaptation Plan for Action (2007), "UN-supported process to identify priority activities and immediate needs with regard to adaptation to climate change", accessed May 2010 at www.preventionweb.net/files/8581_zmb01.pdf.

34. Heath, T (2010), "Zambia climate change briefing", WSUP, Cranfield University, accessed October 2010 at www.wsup.com/sharing/Resources.htm; also Ministry of Tourism, Environment and Natural Resources (2007), "Formulation of the national adaptation

improved. This will reduce surface runoff and prevent it building up into high energy torrents that undermine kiosks and damage pipes.

In Kanyama, reducing localized flooding should be the priority. This entails working with the council and utility to develop the drains and clear them of rocks and debris. The main health risks come from latrines being inundated by floodwater and overflowing. Possible adaptations are assistance with emptying and raising latrines, and in the longer term installing decentralized sewerage; however, all the adaptations would rely on improved drainage and the worst latrines are owned by the poor who cannot afford to upgrade. To improve drainage, the local water utility (Lusaka Water and Sewage Company) needs to provide technical support and assist in mobilizing finance, while the council needs to establish better planning and zoning legislation. In addition, to improve the health of the community, the water kiosk network needs to be expanded to ensure that every household is close enough to a water kiosk so that they can access safe water during floods.

programme of action on climate change", UNDP, Zambia, accessed March 2012 at http://unfccc.int/resource/docs/napa/zmb01.pdf.

b. Naivasha – Kenya

Background: Naivasha is located approximately 50 kilometres northwest of Nairobi, next to Lake Naivasha. Profitable and expanding flower and vegetable farms (4,000 hectares[35]) surround the lake, exporting to Europe and providing the basis of the local economy. These have led to a rapid growth in population, as confirmed in interviews and by Becht et al.[36] The farms abstract from the lake and employ cheap labour from the peri-urban areas, and there is conflict over declining water levels, increasing pollution and poor working conditions. Three peri-urban communities were visited, Karagita, Kamera and Mirera (population of 54,000 in 1999[37]). Groundwater is abstracted and supplied via kiosks by a small private network operator under agreement with the water utility, Naivawass. Some water is collected directly from the lake and delivered by donkey carts. The communities suffer from droughts as well as flash floods, which drain into the lake. Sanitation facilities comprise pit latrines.

Climate change: Kenya is classified by the UN as chronically water scarce.[38] Agriculture is the basis of the economy, employing 75 per cent of the population and providing the largest proportion by sector of the GDP,[39] and is very vulnerable to increasing temperatures, droughts and floods. Mean temperature is predicted to increase with a greater frequency of "hot" days and nights and very few "cold" days or nights. Rainfall is anticipated to decrease in volume, increase in intensity and become increasingly irregular (observable in recent years). Extreme events will increase in frequency and intensity and occur in new locations.

Hydrological scenarios: Two scenarios were developed based around changes in the mean lake level. Decreased lake level and increased drought would occur if there were significant increases in evaporation and/or decreases in rainfall. Increased lake level would occur if there was increased rainfall intensity in the upper catchment area, leading to increased runoff and river flow, offsetting potential increases in lake evaporation. Increased rainfall intensity would also increase the number and intensity of flash floods.

Vulnerabilities and impacts: Decreased lake level and increased drought would result in increased domestic demand and a decrease in the

35. Becht, R, E O Odada and S Higgins (2005), "Lake Naivasha: experience and lessons learned", in International Lake Environment Committee Foundation (ILEC), *Lake Basin Management Initiative: Experience and Lessons Learned Briefs, including the Final Report: Managing Lakes and Basins for Sustainable Use, A Report for Lake Basin Managers and Stakeholders*, ILEC, Kusatsu, pages 277–298, accessed August 2010 at www.ilec.or.jp/eg/lbmi/pdf/17_Lake_Naivasha_27February2006.pdf.

36. See reference 35.

37. WSUP (2006), "Feasibility study on improvement of water and sanitation conditions for Mirera-Karagita: Naivasha", Final Report, October, Development Impact Consulting, London, 2 pages.

38. See World Bank (2009b), "Climate variability and water resources degradation in Kenya: improving water resources development and management", Working Paper No 69 34854, accessed October 2010 at www.wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187

283&siteName=WDS&entityID=000090341_20060110161654.

39. Library of Congress – Federal Research Division (2007), "Country profile: Kenya", accessed January 2012 at http://lcweb2.loc.gov/frd/cs/profiles/Kenya.pdf.

availability of surface waters. In the past, borehole levels have remained constant throughout droughts, so there is hope that this would still be the case in the future. However, the shallow wells dry up, so there are longer queues at kiosks, water from vendors becomes more expensive and water takes longer to collect. The community cites that the main problem during droughts is a decrease in household incomes because the flower farms reduce their workforce and market gardening becomes impossible. It means households are less able to pay for water and food, and this is compounded by increases in food prices. As a result, water use decreases, hygiene deteriorates and the prevalence of disease increases.

As the lake is very shallow, the lake area decreases as the level drops, leading to conflicts over abstraction between pastoralists and the commercial farms. Without adequate water, the commercial farms would become unprofitable and would reduce their workforce, leading to unemployment. When the volume of the lake decreases, water quality also deteriorates.

An increase in flash floods would also create problems for the community, as they wash solid waste and silt into the lake, they cause latrines to collapse and overflow, expose pipes, damage houses and crops and inundate roads, which disrupts local businesses and schools. The community emphasized that flash floods are only an inconvenience, but a health professional reported an increase in diarrhoea, typhoid and dysentery during floods.

Climate proofing: The private network operator needs to ensure affordable and accessible water by maintaining low prices at the kiosks. It should support catchment management processes, ensure well heads are properly sealed and provide education about flood-proof latrines. These would be pits that are sealed so that they cannot become flooded with groundwater, and raised above ground level so that they cannot be inundated by surface water. The water utility (Naivawass) needs to adapt its system to better cope with flash floods, especially its sewage treatment plant, which becomes overloaded with stormwater during rain events (although this plant only serves a small proportion of the population). The council needs to maintain and develop drains and terraces and plant trees in the upper catchment area.

c. Antananarivo – Madagascar

Background: The city of Antananarivo consists of a central urban district surrounded by peri-urban settlements and rice farms. The central areas are not segregated by income, and large houses are surrounded by high density, informal low-income houses. These central areas are on the right bank of the River Ikapo and are protected from 1-in-100-year flood events, whereas the peri-urban areas on the left bank only have protection from 1-in-10-year floods. The city is drained by three main drains, which are inadequately maintained and flood throughout the rainy season. Eight low-income communities were visited, four urban and four peri-urban. Water user associations in these communities buy water from the water utility and sell it from kiosks. Sanitation facilities comprise pit latrines, although there is a sanitation marketing programme promoting sanplats. Solid waste management is limited.

Climate change: The mean temperature is expected to increase; by 2055, the south of the country will be 2.6°C warmer and the north and coastal areas 1.1°C warmer.[40] Mean rainfall and rainfall intensity will increase throughout the summer months; during the winter months the north will be wetter with more frequent storms, while the south will be drier. Unusually, these predictions for the future are the reverse of the current trend. The frequency of cyclones is expected to decrease in the early part of the main season (November to March), but their intensity and destructive power are expected to increase towards the end of the century.

Hydrological scenarios: All the climate models predict that Antananarivo will experience increases in total rainfall and intensity – hence this was the only hydrological scenario considered. An increase in total rainfall is likely to increase runoff and raise river levels, while increases in rainfall intensity are likely to cause more intense flooding from the river and the drains. Even if the frequency of flooding does not change, the increase in river levels will increase the number of days when the city drains cannot drain naturally and have to be pumped. If the pumps fail or are overwhelmed, flooding will occur.

Vulnerabilities and impacts: In the informal urban areas, the frequency and severity of flooding from the drains are likely to increase. Flooding is a major health risk and disrupts the lives of communities. Water gets into houses, employment decreases, travel is difficult and the environment becomes dirty, odorous and very unpleasant. Household latrines overflow, their superstructures and pits collapse, the use of flying toilets increases (defecation in plastic bags), there are long queues at kiosks, taps can be submerged and water pressure is lower. The water supplied by the water utility (JIRAMA) is contaminated during heavy rains. Deforestation in the catchment area means that there is soil erosion, so larger amounts of sediment enter the water treatment works along with other pollutants, as there is no catchment protection.

The upland peri-urban areas may experience increased surface runoff, while the lowlands and rice paddies could experience flooding from the drains or the river. The impacts would be similar to the urban areas, with the addition of damage to crops and livestock, and greater livelihood vulnerability. However, in the peri-urban areas there is typically more space to implement local coping mechanisms.

Climate proofing: There is already an awareness of the importance of addressing the poor sewage and stormwater management in Antananarivo, and a sanitation master plan has been developed. The adaptation priority should be to support this existing plan, emphasizing the fact that flood risk will become more significant, and more resources should be dedicated to flood mitigation. Additional adaptations were also identified for 40 areas modelled[41] as being especially vulnerable to flooding. In these areas, water providers should monitor water quality and chlorinate, and should provide education on flood proofing latrines. The water utility (JIRAMA) should undertake a programme of leak detection and pipe maintenance, and reduce illegal connections to minimize contamination of the water supply and improve the hydrostatic pressure. Their treatment system also requires additional stages to cope with the high sediment load in the inlet water during floods. The municipality needs to focus on clearing the drains and helping the other organizations responsible for drainage; they should also improve solid waste management and sanitation in order to reduce dumping in drains. It is also important that they stop people from settling on flood-prone areas. These ideas need mainstreaming into the

40. Conservation International and WWF (2008), "Assessing the impacts of climate change on Madagascar's biodiversity and livelihoods", Workshop Report, MEEFT, Conservation International, WWF, MacArthur, USAID, accessed October 2010 at marineclimatechange.com/Marine_Climate_Change_Workshops/Madagascar_files/CI-WWF%20Madagascar%20Workshop%20Report%20FINAL.pdf.

41. SOMEAH (2010), "Outlining a sanitation strategic plan for the agglomeration of Antananarivo. Phase 1: assessment of the sanitation situation", 20 127 R1, WSUP Madagascar, 173 pages.

TABLE 3
Stakeholders' awareness of climate change and their plans to adapt

Stakeholder	Awareness	Plans/actions	Number of interviews
Community	Limited	None	30
Local service providers	Limited/medium	No direct plans	26
Utility	Limited/medium	No plans – aware need to adapt system but no direct plans	5
Council	Medium	No direct plans – Lusaka council has climate change department	7
Government	Awareness at policy level but little implementation	Involved in UNFCCC dialogue; some form of climate change department/networking organization; REDD process (deforestation); little regional or district work being completed, seen as issue for central government	19
Researchers	High	Studies being undertaken and advocacy work	3
NGOs	Most have high awareness, but some have limited	No direct plans; impact and vulnerability assessments; set up partnerships/advocacy forums	14
Consultants	Medium	No current projects	2
Local business	High	Aware of need to incorporate the impacts	2

plans and actions of the stakeholders, and some additional funding will also be required. All of these actions required by the municipality are challenging, given the current unstable political situation.

d. Climate change awareness

During the three case studies, the overall awareness of climate change was qualitatively reviewed and the results for the different stakeholder groups are summarized in Table 3. Local institutions, water utilities and communities in the three cities were mostly unaware of climate change and have few plans to adapt. In government, there is generally some awareness at the policy level but little impact on the ground. However, even in high-income countries, awareness of climate change can be lacking at all levels; for example, Tompkins et al. found that in the UK, climate change adaptation had been dominated by national government initiatives and little had trickled down to local government level.[42]

42. Tompkins, E, N Adger, E Boyd, S Nicholson-Cole, E Weatherhead and N Arnell (2010), "Observed adaptation to climate change: UK evidence of transition to a well-adapting society", *Global Environmental Change* Vol 20, No 4, pages 627–635.

IV. DISCUSSION

a. Commonalities between case studies

In all the case studies, floods had a bigger impact than droughts, and the interviewees' perception was that changes in mean temperature would have no impact on water and sanitation. Of the 11 communities visited, eight were vulnerable to flooding and four to water shortages. Table 4

TABLE 4
Impacts on low-income urban areas

Flooding	Drought
Within the community	
Pipes exposed	Water shortages
Taps submerged	Water price increases
Siltation of water resources	Less water for health and hygiene
Contamination of boreholes	Long queues at kiosks
Latrines inundated	Water pressure drops
Latrines and buildings collapse	Livestock suffers
Solid waste dispersed	Peri-urban and garden crops destroyed
Water in houses	Increased poverty
Roads impassable, increasing the cost of charcoal and food	Education suffers (less money for school fees)
Disease increases, especially malaria, dysentery and diarrhoea	Malnutrition
Employment decreases	Health issues
Income-generating activity decreases	
Outside of the community	
Utility infrastructure damaged	Surface and groundwater availability decreases
Increased water treatment costs	Increased abstraction conflicts
Crops damaged	Food insecurity – food costs increase
Road network damaged	Hydroelectricity shortages

presents impacts common across the communities, divided into impacts within the community and impacts outside the community (on a citywide, regional or national scale). The impacts outside the community can have a larger overall effect as they affect more people, cause more damage and often need action by governments and institutions; for example, during a regional drought everyone is impacted by food price increases.

The recommended adaptations can be split between adaptations to droughts and floods, and whether they should be undertaken by local service providers, utilities or municipalities. They are specific to each city and can be found in full in the city specific reports.[43] These common adaptations are a mixture of infrastructure, monitoring programmes and education (Table 5). They demonstrate that adapting to climate change does not involve many new processes – most adaptations could equally be described as good practice in flood or drought-prone areas.

43. See reference 32, Heath et al. (2010a); also see reference 32, Heath et al. (2010b); and see reference 32, Heath et al. (2010c).

b. Implications of findings

Figure 1 synthesizes how changes in rainfall (identified as the most significant climate change) impact upon flood and drought-prone areas. There will be some benefits associated with climate change, for example increased rainfall will have a positive impact on communities in drought-prone areas; however, in most cases the negative aspects will be more significant. And even in drier futures, if the frequency and intensity of extreme storms increase, flooding may not reduce.

The results indicate that it is increases in extreme events rather than changes in averages that will cause the most damage to communities and infrastructure, at least in the next few decades. This conclusion is shared

TABLE 5
Common adaptations recommended for areas at risk of flooding or drought

Risk of water shortages (drought)	Risk of flooding
Local service providers	
• Ensure affordable and accessible water supply • Expand kiosk network into unserved areas • Investigate alternative supplies for use during droughts • Hygiene promotion and community education on the risks to health during droughts	• Hygiene promotion and community education on the risks associated with floods • Education on best practice for latrine construction to avoid latrines collapsing or overflowing • Protect boreholes and pipe network from flooding • Regular sanitary inspections during floods • Tighter enforcement against fly tipping • Chlorinate water supply during floods
Utility	
• Support the expansion of new kiosks • Build new storage tanks • Investigate the recharge rate/sustainable yield of aquifers	• Leak detection and pipe maintenance • Reduce illegal connections and improve the hydrostatic pressure • Monitor water quality during floods • Regular inspection of infrastructure during floods
Municipality	
• Engage in water allocation dialogue	• Improve drainage systems: clear and maintain drains, legislation against dumping • Improve solid waste collection • Subsidize tanker/waste disposal options • Land management activities to reduce severity of floods

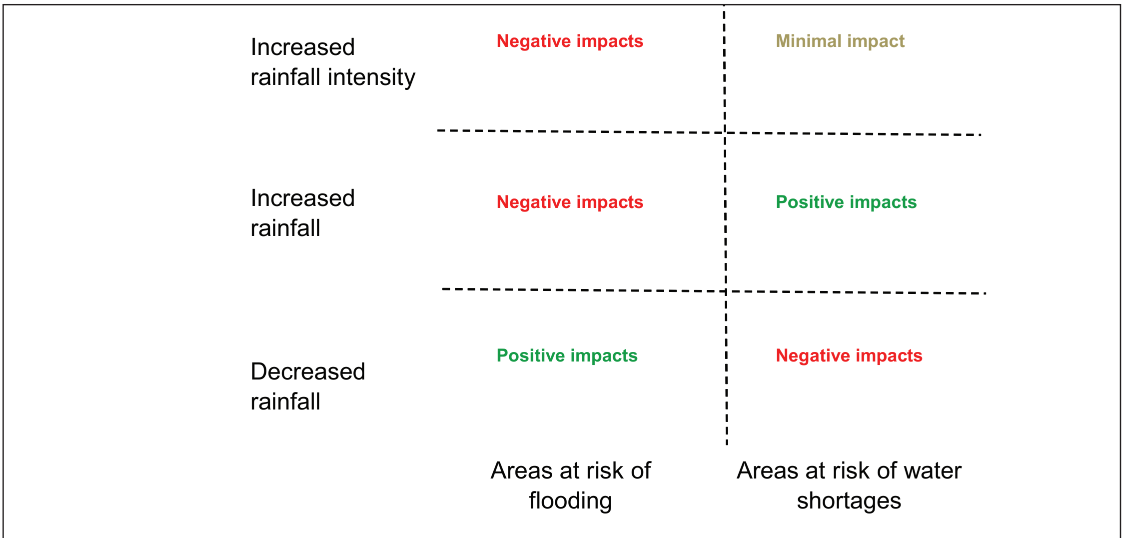

FIGURE 1
Impacts of climate change on flood and drought-prone urban areas

with the CAPNET[44] climate change adaptation guide, which emphasizes building capacity to deal with unpredictable events, managing risk and prioritizing no-regret measures. An increased frequency of extreme events will introduce risks to projects for which current infrastructure is not designed. In particular, increases in rainfall intensity are likely to affect flooding and drainage, for example there may be a higher risk of borehole contamination after heavy rainfall. Examples from regions with experience of more extreme climates will be increasingly helpful to organizations planning adaptations, as they can provide details of potential risks and also design features.

The results support the findings of Sanchez-Rodriguez[45] and Simon[46] that for adaptation to be successful it needs to be integrated within existing plans and prioritized alongside other risks. For example, the sanitation master plan in Antananarivo provides a comprehensive overview of how to adapt to flooding, and the roles of the different stakeholders, based on detailed research. If adaptations are developed externally, they are unlikely to capture the more nuanced details of a locally prepared plan and may introduce competition and confusion. Many adaptation practices are simply good water management. In Lusaka, in particular, service providers have been advised to make such changes for decades; climate change may prove to be the catalyst for making this happen.

Allen et al.[47] found that the poor have a certain level of built-in resilience (preventative and impact-minimizing economic strategies, asset accumulation, social support networks) that must be recognized and better supported by planning initiatives. However, for the communities visited it was found that the level of built-in resilience was minimal due to limited assets and resources. This is compounded by the poor services they receive with respect to water, sanitation, drainage and solid waste collection. A limited education also traps people into a cycle of poverty and sentences them to life in informal settlements.

The limited climate change awareness among stakeholders reinforces the need for a rapid and affordable method to assess the impacts of climate change at both the vulnerability and modelling level, in order to identify pragmatic and rigorous adaptations to climate change. This is supported by the findings of Satterthwaite et al.[48] that local government fails to address efficiently the impacts of climate change. Sanchez-Rodriguez[49] similarly found that a thorough vulnerability analysis and impact assessment for enabling appropriate design and implementation of adaptation measures is lacking in almost all low- and middle-income countries; and Muller[50] found that few countries have begun to review their design standards from a climate change perspective. Adaptations that also help to reduce vulnerability to current problems will help mitigate opposition to spending on adaptation for the longer term, and will allow a quicker start. This is especially important as the infrastructure built today locks providers into patterns of behaviour for many years to come.[51]

c. Evaluation of the RCAA method

Essentially, the RCAA identifies the adaptations that local service providers should implement to increase their climate resilience, and the adaptations required by the utility and municipality to support them.

44. CAPNET (2009), "IWRM as a tool for adaptation to climate change. Training manual and facilitator's guide", REDICA, CAPNET Brazil, APFM/WMO and UNESCO–IHE, accessed March 2010 at www.cap-net.org/node/1628.

45. See reference 25, Sanchez-Rodriguez (2009).

46. See reference 25, Simon (2010).

47. Allen, A, C Johnson and H Jabeen (2009), "Built-in resilience: learning from grassroots coping strategies for climate variability", *Environment and Urbanization* Vol 22, No 2, October, pages 415–431.

48. Satterthwaite, D, S Huq, M Pelling, H Reid and P Romero Lankao (2007), *Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-income Nations*, IIED, London, accessed January 2010 at pubs.iied.org/10549IIED.html, 124 pages.

49. See reference 25, Sanchez-Rodriguez (2009).

50. See reference 24.

51. See reference 24.

Its main strengths are that it applies regional climate modelling to local vulnerabilities; it is based on multiple scenarios describing the possible impacts of possible futures; and it was developed and trialled based on fieldwork, ensuring that it is workable and relevant. The RCAA draws heavily upon the Vision 2030 overview of the vulnerabilities of water and sanitation technology and potential adaptations, but integrates them within the context of the existing vulnerabilities. The RCAA incorporates the community approach used in CRiSTAL and the assessment of existing climate vulnerabilities used by USAID. However, the RCAA does have limitations and these are outlined for each stage below.

i. Limitations

The uncertainties associated with climate modelling make it difficult to quantify the climate changes at local level, and dangerous to rely on detailed scenarios. Changes to tropical precipitation are particularly uncertain because of uncertainties with the positioning of the Inter-tropical Convergence Zone.[52] Climate predictions are ideally given as probabilities or as most likely values with wide ranges. This uncertainty is often magnified when calculating the impacts, and the climate uncertainty is even greater at the city scale as there has been little downscaling of the models and the predictions are based on interpolations. The exception for this study was in Madagascar, where there had been detailed modelling and analysis of the region.

52. McSweeney, C, M New, G Lizcano and X Lu (2010), "The UNDP climate change country profiles: improving the accessibility of observed and projected climate information for studies of climate change in developing countries", *American Meteorological Society* Vol 2, pages 157–166.

In Lusaka and Naivasha, community data were collected using individual interviews, while focus groups were used in Antananarivo. The questions asked were the same throughout, but the focus groups proved to be a more efficient way of getting information: a broader range of impacts was identified and groups often verified their answers through the discussions. With both methods it was difficult to explore the impacts of possible new risks, as the community had direct experience. However, it is worth noting that Adelekan[53] successfully obtained specific data on flooding impacts in Lagos (Nigeria) through individual interviews, using local enumerators. Similarly, Douglas et al.[54] used a technique developed by ActionAid called Participatory Vulnerability Analysis, which explored the reasons for flooding and what community action is possible. Their local representatives obtained some vivid descriptions of how individuals reacted to the flooding. From these examples, it becomes clear that local interviewers can obtain better information than external ones; however, training local interviewers may not be possible within the short timescale of an RCAA commissioned by an external agency. Yet, it was difficult to explore the impacts of possible new risks as the community had not directly experienced the effects.

53. Adelekan, I (2010), "Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria", *Environment and Urbanization* Vol 22, No 2, October, pages 433–450.

54. Douglas, I, K Alam, M Maghenda, Y McDonnell, L McLean and J Campbell (2008), "Unjust waters: climate change, flooding and the urban poor in Africa", *Environment and Urbanization* Vol 20, No 1, April, pages 187–206.

The interviews with more educated individuals, including community leaders, were more insightful, requiring less probing to highlight secondary issues. The main limitation was that more relevant concepts emerged as interviews progressed, so that discussion of these was missed with early informants. To address this, some of the stakeholders were interviewed again at the end of the fieldwork.

Converting climate changes into local impacts is the most uncertain aspect of the RCAA, largely due to the lack or low quality of hydrological and climate data. A conceptual hydrological model based on hydrological principles was developed and used to define scenarios for the various climate projections. However, great uncertainty remains in estimating the effect on infiltration (affecting both recharge and runoff) due to the interrelated nature of hydrological processes, especially when rainfall volume is predicted to decrease while its intensity increases. This is significant, as small changes in rainfall and/or intensity are amplified in the catchment response, often leading to large changes in stream flow.[55]

55. See reference 24.

The assessments of the impacts of the various scenarios provided a clear insight into the nature of the risks; however, sometimes the intensity of the impacts was difficult to clarify. Likewise, most of the climate-proofing process effectively identified appropriate adaptations; but for some impacts there was insufficient knowledge of the system design, layout and soil structure, or insufficient information on existing plans to be able to provide detailed specifications. This could be addressed by focusing on these aspects during subsequent fieldwork.

The main external limitations are that the water and sanitation services that are to be climate proofed are mostly in informal settlements in urban or peri-urban areas, where there are lower income levels and deficient basic services. The tariffs collected often do not cover operation and maintenance costs, let alone provide revenue for future investment. Therefore climate change adaptations will often be secondary to providing basic supplies and meeting current needs. However, it should be noted that when populations migrate to cities from areas experiencing extreme environmental change, this may present opportunities for them to receive better services and become less vulnerable overall.[56]

56. Government Office for Science (2011), *Foresight: Migration and Global Environmental Change – Future Challenges and Opportunities*, Final Report, Government Office for Science, London, 234 pages.

V. CONCLUSIONS

The lack of climate change awareness in low- and middle-income countries means that it is essential to have a simple method to climate proof water and sanitation services for the urban poor in these countries. The main risks to water and sanitation provision are from changes to the frequency and intensity of extreme hydrological events, especially an increase in floods or droughts. The RCAA is an effective tool for climate proofing, as it converts regional climate predictions into local adaptations. In addition, by dividing adaptations between the stakeholders, awareness is raised at the appropriate levels.

Applying the RCAA highlighted the fact that adapting to climate change does not necessarily involve many entirely new processes or techniques; instead, it requires a combination of capacity building and technological and managerial measures. Water providers should not consider climate change in isolation but should rank and prioritize it against other sources of change, risk and uncertainty. They need to focus on increasing the environmental resilience and disaster preparedness of projects and the robustness of existing systems. It should, however, be made clear that this is not an argument for "business as usual", and climate change adaptations should not simply be "bolted on" to existing plans. In particular, risks arising from increases in rainfall intensity and more frequent extreme events should be considered.

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