

SUMMARY AND POLICY IMPLICATIONS

VISION 2030



THE RESILIENCE
OF WATER SUPPLY
AND SANITATION
IN THE FACE OF
CLIMATE CHANGE



SUMMARY AND POLICY IMPLICATIONS

VISION 2030

THE RESILIENCE OF WATER SUPPLY AND
SANITATION IN THE FACE OF CLIMATE CHANGE

WHO Library Cataloguing-in-Publication Data

Summary and policy implications Vision 2030 : the resilience of water supply and sanitation in the face of climate change.

1.Water resources development. 2.Water supply. 3.Sanitation. 4.Climate - trends. 5.Public policy. 6.Forecasting. 7.Potable water 8.Technolgy transfer.
9.Developing countries. I.World Health Organization. II.United Kingdom. Department for International Development (DFID).
III.The resilience of water supply and sanitation in the face of climate change.

ISBN 978 92 4 159842 2

(NLM classification: WA 675)

© World Health Organization 2009

All rights reserved. Publications of the World Health Organization can be obtained from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int). Requests for permission to reproduce or translate WHO publications – whether for sale or for noncommercial distribution – should be addressed to WHO Press, at the above address (fax: +41 22 791 4806; e-mail: permissions@who.int).

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

Printed in France

FOREWORD

Providing access to safe drinking-water and basic sanitation is a proven engine driving development and promoting health. The water and sanitation targets of Millennium Development Goal 7 have galvanized the international community into a collective effort towards achieving sustainable access to drinking-water and sanitation for millions of people. To safeguard these achievements, we must remain vigilant to emerging trends and risks that could derail our efforts and undermine our impact on poor communities.

Climate change is now recognized as one of the defining challenges for the 21st century. More frequent and intense extreme weather events have resulted in a higher incidence of floods and droughts around the planet. The ensuing adverse impacts on water and sanitation services constitute a clear and present danger for development and health. New evidence, translated into new advocacy, is needed to raise the awareness in governments, international agencies, nongovernmental organizations and communities about the links between climate change and water and sanitation services, and the

consequences for health and development. In a context of relative uncertainty associated with climate change projections, policy responses will have to be formulated based on our current knowledge to address these impacts and consequences.

This document summarizes the evidence for the impact of climate change on water and sanitation technologies in the near to medium term. It aims to help policy-makers, planners, operators and communities in making practical decisions based on clear criteria, to improve the resilience of their water and sanitation services. It is part of a larger set of materials, including a full technical report and a set of background reports and guidance notes, available on the accompanying CD-ROM.

WHO and DFID have collaborated to carry out this study which has brought together our joint knowledge and expertise in water, sanitation, health and development. Ensuring optimal resilience of water and sanitation services in a globally changing climate context will be crucial to maintaining the momentum of making progress in health and development.

Dr Maria Neira

Director

Department of Public Health and Environment

THE VISION 2030 STUDY

Drinking-water and sanitation are foundations of public health and development. Citizens in developed countries take them largely for granted, yet they are carefully regulated by governments. In the developing world they are targets of development policy.

Global climate change has been on the international agenda for over a quarter of a century. The process of climate change has been confirmed to be ongoing and some further changes are now considered unavoidable. Most impacts will be experienced through more droughts, floods, and less predictable rainfall and water flows. These will place established water and sanitation services – and future gains in access and service quality – at real risk. The impacts are likely to be dramatic and severe for the billions of people who continue to seek the elusive goal of meeting their own basic needs. The effects of climate change could also cause a substantive set-back in the developed world among those who feel confident that they have secured access to basic services.

The Vision 2030 Study set out to increase our understanding of how and where climate changes anticipated in the mediumterm will affect the drinking-water and sanitation situation; what can be done to optimize the technologies and systems that exist to maximize their resilience; and what needs to be done differently to ensure that the services of the future can cope with the impacts of climate change. It focuses particularly on low- and middle income countries, where risks from climate change are greatest, and where access to water supply and sanitation services is more limited.

The study brought together evidence from projections on climate change, trends in technology application, and developing knowledge about the adaptability and resilience of drinking-water and sanitation. While the reports emanating from this study focus on issues related to the provision of water and sanitation services, installing services with a greater resilience to the impacts of climate change will rely in turn on improved management of water resources. Water resources management in this context has been extensively discussed, for example in the technical paper on water of the Intergovernmental Panel on Climate Change.

The CD-ROM that accompanies this booklet includes:

- the full technical report on which this summary is based;
- a detailed report on climate change projections;
- a detailed report on technology projections;
- a detailed review of resilience and adaptive capacity, including a series of technology-by-technology fact sheets.

FIVE KEY CONCLUSIONS OF THE VISION 2030 STUDY

1. Climate change is widely perceived as a threat rather than an opportunity. There may be significant overall benefits to health and development in adapting to climate change.

- Efforts to adapt to climate change would create a stimulus to aim directly for higher levels of service for those currently unserved, without passing through the intermediate step of communal levels of services.
- A focus on adaptation to climate change puts greater emphasis on the need to address water source sustainability from the outset of new programmes and not simply as an afterthought.
- Concern about adapting to climate change creates stronger pressure to rationalize the choice of technologies to be used to deliver sustainable and effective services.

2. Major changes in policy and planning are needed if ongoing and future investments are not to be wasted.

- Technologies capable of adapting to the range of climate scenarios need to be identified and prioritized. Some widely-used technologies will be unsustainable in some areas. Human and institutional capacities and investments need to be redirected towards sustainable solutions.
- Technologies and planning are needed that can be adapted to cope with multiple threats and not only climate change.
- Reducing water use and better demand management will be critical in managing increased piped water supply and water-

using sanitation, especially where rainfall declines.

- Community-managed drinking-water sources and supplies fail early and are frequently contaminated. Climate change will aggravate this.

3. Potential adaptive capacity is high but rarely achieved. Resilience needs to be integrated into drinking-water and sanitation management to cope with present climate variability. It will be critical in controlling adverse impacts of future variability.

- Urgent action is required to turn the potential adaptive capacity of many utility-managed water supplies to actual resilience to climate change.
- Systematic assessments of the climate change resilience of all utilities and of rural water and sanitation programmes are needed.
- Adaptations that are available need to be put in place in areas likely to face climate changes.

4. Although some of the climate trends at regional level are uncertain, there is sufficient knowledge to inform urgent and prudent changes in policy and planning in most regions.

- In sub-Saharan Africa, access to basic water supply and sanitation is low, and early adaptation is required to avert a decline in progress. In many countries this implies technology shifts.
- In North Africa and the eastern Mediter-

anean, already dry regions with high coverage and service levels, there is an urgent need to manage services and water resources to avoid further water scarcity.

- In Asia, drinking-water coverage is high with much rural reliance on protected wells. Flooding and decreasing reliability of surface waters may become major challenges.
- In central and northern South America projections suggest drying combined with infrastructure damage from extreme events.

5. There are important gaps in our knowledge that already or soon will impede effective action. Targeted research is urgently needed to fill gaps in technology and basic information, to develop simple tools, and to provide regional information on climate change.

- There are technology gaps – for example, in widely-acceptable alternatives to sewerage for cities; and in the application of data capture and signaling to inform better monitoring.
- There are significant gaps in basic information – for example, in understanding the water resource base; and on water demand from household-level access to drinking-water.
- Simple tools are needed in various areas – for example, for rapid assessment of the vulnerability of water utilities to climate change.
- There is a lack of detailed information on climate change at regional level.

WHY RESILIENCE TO CLIMATE CHANGE IS IMPORTANT

Climate variability is already a threat to water supplies and sanitation.

Floods are “normal” occurrences that continue to cause shocks for affected populations and to challenge water and sanitation managers. In many places they are likely to become more frequent with climate change.

- Floods can have catastrophic consequences for basic water infrastructure. Such damage can take years to repair.
- On a smaller scale, drinking-water infrastructure can be flooded and put out of commission for days, weeks or months.
- Where flooding of sanitation facilities occurs, there may not only be a break in services, but the flooding may distribute human excreta and its attendant health risks across entire neighbourhoods and communities.

Droughts occur, unpredictably, worldwide. In many places they are likely to become more frequent and widespread with climate change.

- Falling groundwater tables and reduced surface water flows can lead to wells drying up, extending distances that must be travelled to collect water, and increasing water source pollution. In response, drilling rigs – which would otherwise be used to increase access – may be redeployed to renew or replace out-of-service wells, slowing progress in extending access.

A quarter of the world’s population live in coastal areas, many of which are water-stressed and experiencing rapid population growth. Coastal areas experiencing sea level rise may become uninhabitable, displacing populations or forcing currently secure water sources out of use because of saline intrusion. This is of particular concern for low-lying small islands and very low-lying countries such as Bangladesh.

Where **long-term rainfall increases**, groundwater levels may rise, decreasing the efficiency of natural purification processes, increasing risks of infectious disease and of exposure to toxic chemicals.

Potential **indirect effects of climate change** on the water supply and sanitation situation include the impacts of energy interruptions, increasing the unreliability of piped water and sewerage services.



Both South Africa and Yemen have suffered extended dry periods or droughts in recent years.

The Kosi Barrage breach in Nepal in 2008 caused widespread damage and loss of life and livelihoods.

In Mozambique in 2000, flooding of 3000 septic tanks caused widespread contamination in Chokwi and Xia-Xia cities.

Floods in Bangladesh in 2007 caused widespread contamination of tubewells.

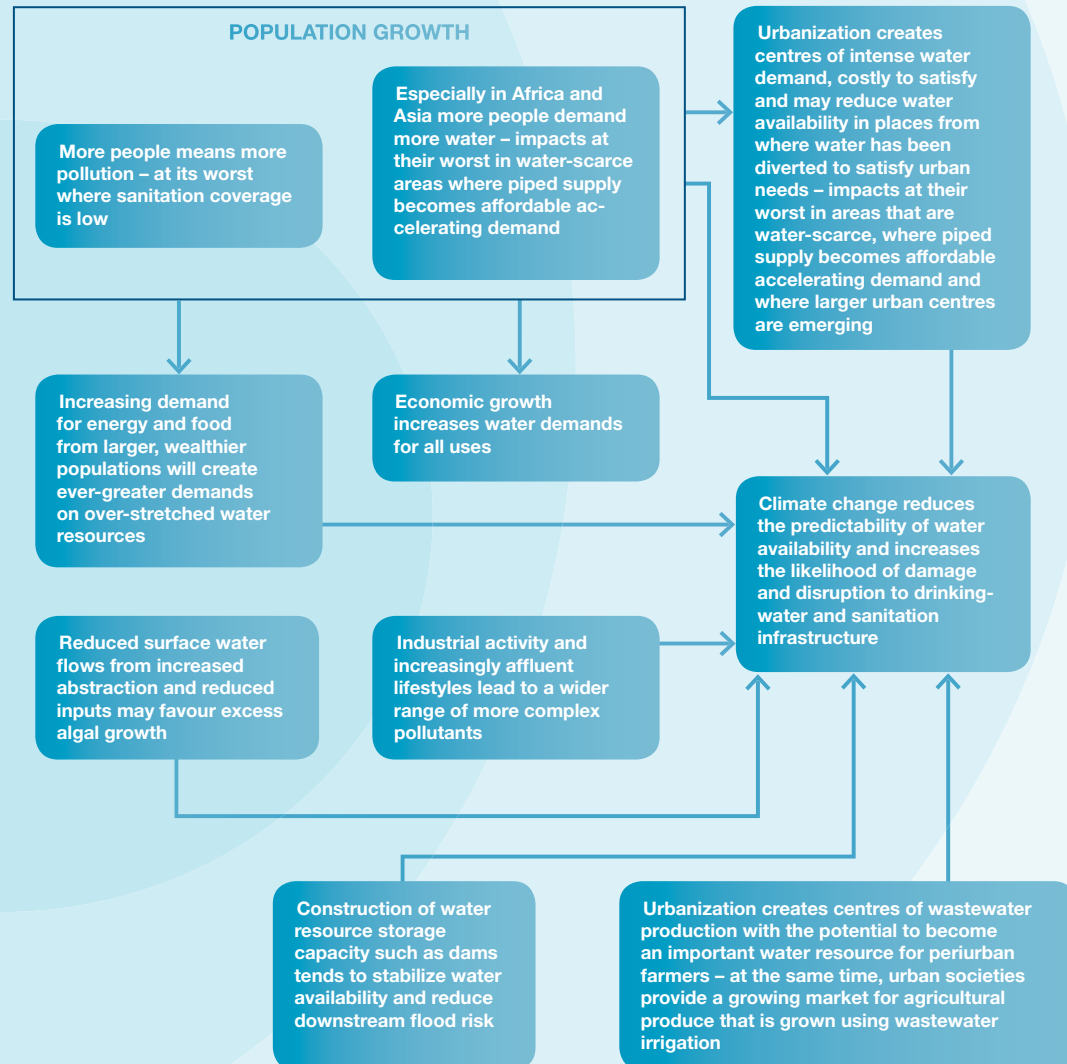
Climate change is not happening in isolation. Some challenges, such as changes in water demands from other sectors, may exacerbate the impacts of climate change. Other developments, such as increased reuse of wastewater for agriculture, may reduce these effects.

Climate change is thus best understood as an additional factor in a complex network of interactions (Figure 1). Technologies and planning are needed that can adapt to cope with multiple threats, rather than to climate change alone.

Water supply and sanitation are affected *by* climate change and have an impact *on* climate change. The carbon footprint of water supply and sanitation – through energy used in pumping, for example – can be significant. Adaptation measures should take this into account. Single measures, such as demand management and leakage minimization, have considerable potential to contribute to both mitigation of adverse effects and adaptation of technologies and systems to increase resilience. Improved planning procedures and the development and deployment of new technologies will support adaptation and mitigation in response to multiple adverse impacts, not just those from climate change alone.

Figure 1

Impacts of climate change in a context of multiple challenges



VISION 2030: THE RESILIENCE OF WATER SUPPLY AND SANITATION IN THE FACE OF CLIMATE CHANGE



The 2030 Vision Study was designed and commissioned by the United Kingdom Department for International Development (DFID) and the World Health Organization (WHO). It intends to define what needs to be done differently to ensure that the water and sanitation services of the future can cope with the climate changes we can anticipate.

The evidence it brought together from projections on climate change, trends in technology application and developing knowledge about drinking-water and sanitation adaptability and resilience is used

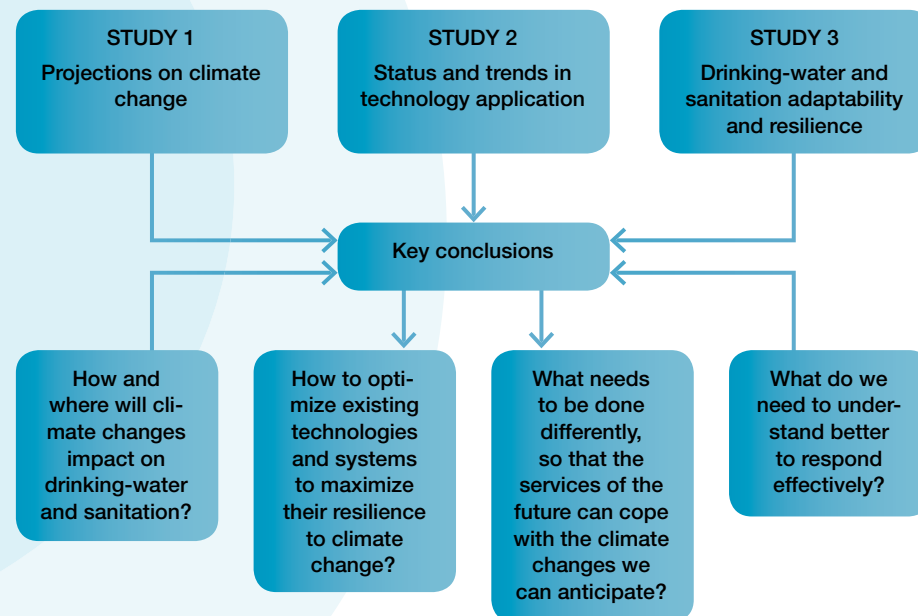
to identify key policy, planning and operational changes that will be required, and to identify critical knowledge gaps.

The structure of the present booklet reflects the study components and conclusions, as outlined in Figure 2.

Key conclusion 1. Climate change is widely perceived as a threat rather than an opportunity. There may be significant overall benefits to health and development in adapting to climate change.

Figure 2

Structure of this report: studies, conclusions, future actions



THIS STUDY LOOKS AT TWO TIME HORIZONS: 2020 AND 2030

2020

- Conditions in 2020 reflect the expected working life of much of the technology and infrastructure already installed or being installed and therefore the policies and planning of recent decades.
- Some of this infrastructure has been in place for a long time and much has been or is being installed as part of efforts to meet the drinking-water and sanitation targets of Millennium Development Goal (MDG) 7 (see Box 1).
- This time horizon gives an indication of the potential for short-term climate change to undermine short-term sustainability.
- Study findings at the 2020 time horizon are useful in understanding required changes to the management of infrastructure already in operation.

2030

- 2030 represents a time horizon by which current policy changes and planning could have influenced technology selection and management practices, including investment decisions.
- The predicted changes in climate by 2030 will have significant impacts. A failure to adapt is likely to have significant adverse consequences.
- Study findings at the 2030 time horizon are useful in understanding policy changes required to ensure that as much as possible of the infrastructure in place in 2030 is both resilient to climate change and managed to reduce risks as far as possible.



Box 1

The Millennium Development Goals

In 2000, heads of state gathered at a special session at the United Nations in New York and adopted the Millennium Declaration. This provided the basis for the formulation of eight Millennium Development Goals (MDGs) aimed at achieving the objective of radically reducing poverty worldwide.

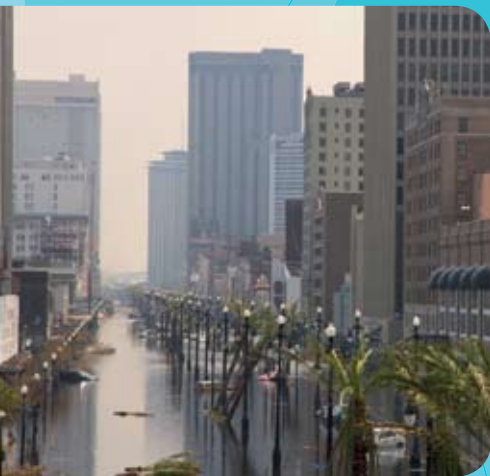
One target under MDG 7 is to halve the proportion of the population without sustainable access to safe drinking-water and basic sanitation by 2015.

Progress towards achieving the global drinking-water component of this target is on track, although this is based on a low level of service: access to a community water source, not water at the individual home. Progress in Africa is

slow. Progress towards achieving the global sanitation component is badly off track.

Increased loss of functioning infrastructure as a result of climate change would set back progress in water and sanitation and, indirectly, towards other MDG targets.

PROJECTIONS ON CLIMATE CHANGE



Decadal forecasts (see Box 2) were prepared by the Hadley Centre in the United Kingdom on likely average precipitation changes and on the likely changes in frequency of heavy five-day rainfall events for 2020 and 2030. The forecasts for 2020 show large-scale impacts that carry on to 2030. By 2030 other impacts are also being detected, as shown in Figure 3. Some of these appear to be consistent with trends identified by the Intergovernmental Panel on Climate Change for 2050 and beyond. In addition to overall, longer-term trends, year-to-year variability will play a role in defining the expected changes. At times, this will exacerbate the changes highlighted here.

Although decadal forecasting does not give specific forecasts of flooding and likely flood events, it is likely that the intensity of wet five-day large-scale weather events will increase in most parts of the world (see the detailed report on climate change projections on the accompanying CD-ROM). The potential for local flooding is also likely to increase in many regions.

Box 2

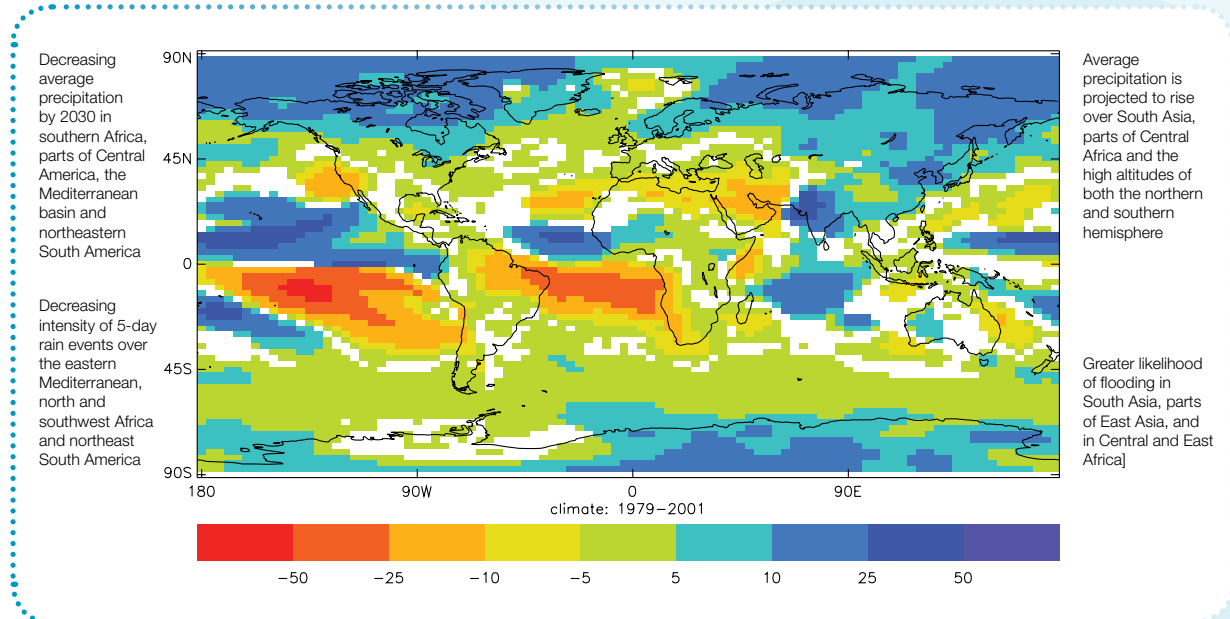
Decadal forecasts

- Decadal forecasts refer to “near-term” climate predictions, from years to several decades ahead. They are derived from climate models which include man-made influences on the climate system; in addition, unlike longer-term (century) predictions, they also include information on the current state of the climate, thus allowing variations resulting from natural causes to be better represented.
- In the near term, changes associated with natural variability and changes arising from man-made influences are expected, in places, to be of similar magnitude, making it essential to represent both in climate predictions for decadal timescales. The design of decadal prediction systems makes them an ideal tool for the purpose.
- Decadal predictions are still experimental. At this early stage in their development technical issues may limit their accuracy at regional scales. Expert advice is needed to assess the reliability of predictions for specific applications.

Source: Met Office Hadley Centre, United Kingdom.

Figure 3

Forecast precipitation changes by 2030



STATUS AND TRENDS IN TECHNOLOGY APPLICATION



The technology projection study has provided projections for 2020 of overall coverage and the principal technologies contributing to coverage (see Box 3), by country, for both rural and urban areas. The maps in Figures 4 to 7 summarize projections to 2020 for urban and rural coverage for water and sanitation.

These projections of both rural and urban water supply and sanitation coverage show the ongoing importance of household-managed sanitation. Combined with the findings on technology resilience (Table 1 on page 15), they provide insight into the likely future of sanitation for most of the world's population.

Technology projection study – issues and lessons learned

The simple projection methods we used do not account for changes in economic, social, political and other factors, which are important but unpredictable. It is unlikely that a more sophisticated model would provide reliable information to 2030 or beyond.

Box 3

The WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation

The WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation (JMP) is the official United Nations mechanism to monitor progress towards meeting the MDG drinking-water and sanitation targets. It estimates coverage separately for rural and urban areas, for each country, MDG regions and worldwide.

The data used by JMP come from country statistical systems and are derived from censuses and nationally representative household surveys. WHO and UNICEF collate this information and apply a standard approach to estimate status and trends to ensure comparability across countries and over time.

Because a standard method is applied, JMP estimates may vary from countries' own estimates, for example because of differences in classification of technologies constituting "access".

Since 2008 WHO and UNICEF have reported on multiple access categories, instead of a single pass or fail criterion for access.

ACCESS TO DRINKING-WATER IN URBAN AREAS

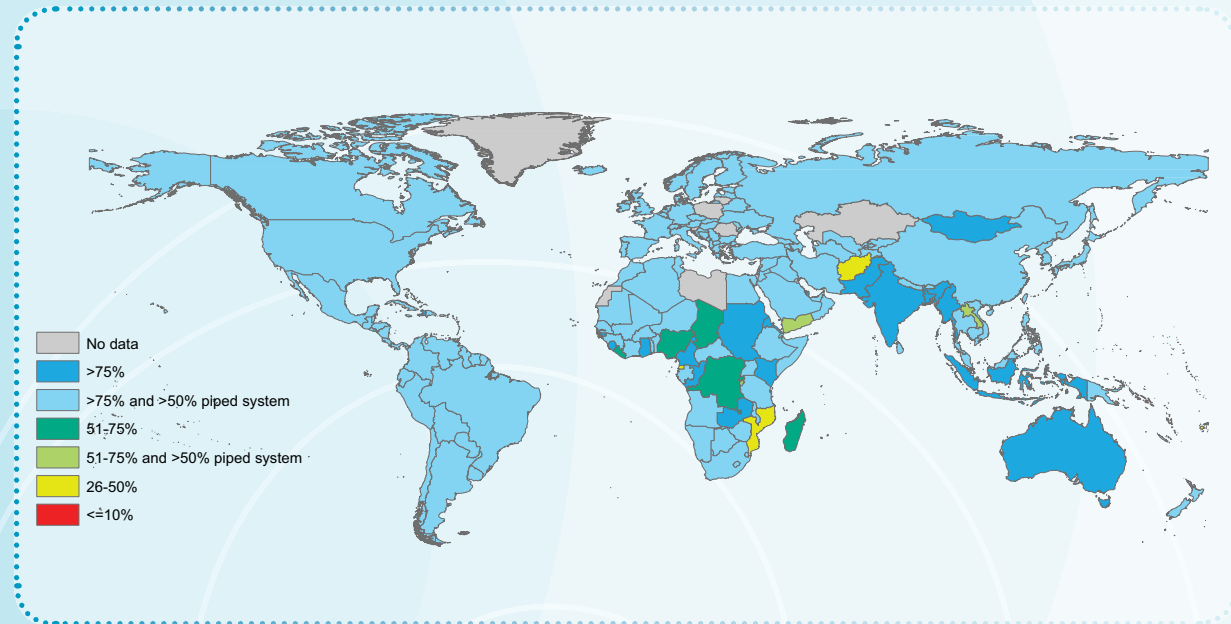
Figure 4 shows overall expected coverage with access to urban water supply by 2020.

The majority of urban dwellers (an estimated 76%) will receive their drinking-water through piped systems at home.

Many people in low-income urban areas rely on community water sources, such as tubewells in Asia and protected springs and dug wells in Africa.

Figure 4

Forecast urban water by 2020



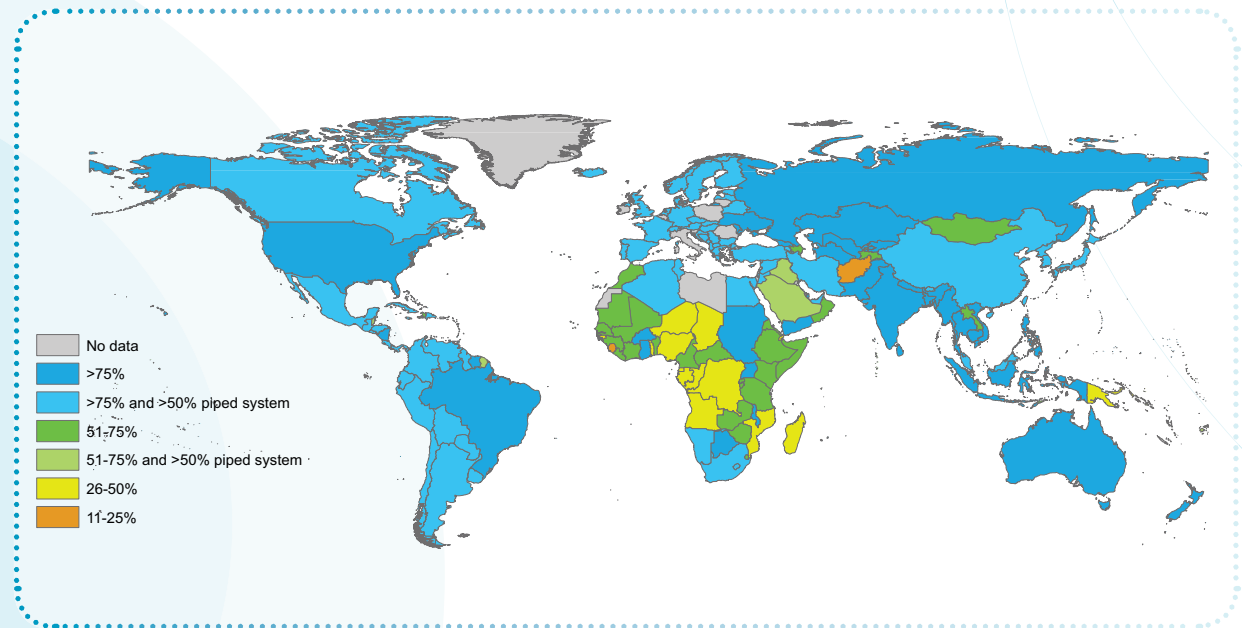
ACCESS TO DRINKING-WATER IN RURAL AREAS

Figure 5 shows overall expected coverage with access to rural water supply by 2020.

Most households without access to improved water sources are rural. The majority of rural dwellers (an estimated 57%) will collect their drinking-water from community sources such as protected wells.



Figure 5
Forecast rural water by 2020



Overall conclusions on drinking-water

- Piped drinking-water coverage is high and increasing, with Africa the only continent with a significant number of countries predicted to have less than 75% piped water coverage 2020.
- Increased piped coverage will add a small but

significant demand on water resources at the same time as pressure from other demands and from climate change is increasing.

- Protected springs and rainwater harvesting are predicted to account for less than 10% of improved water supplies in all regions.
- Use of protected wells is higher in rural compared to urban areas.

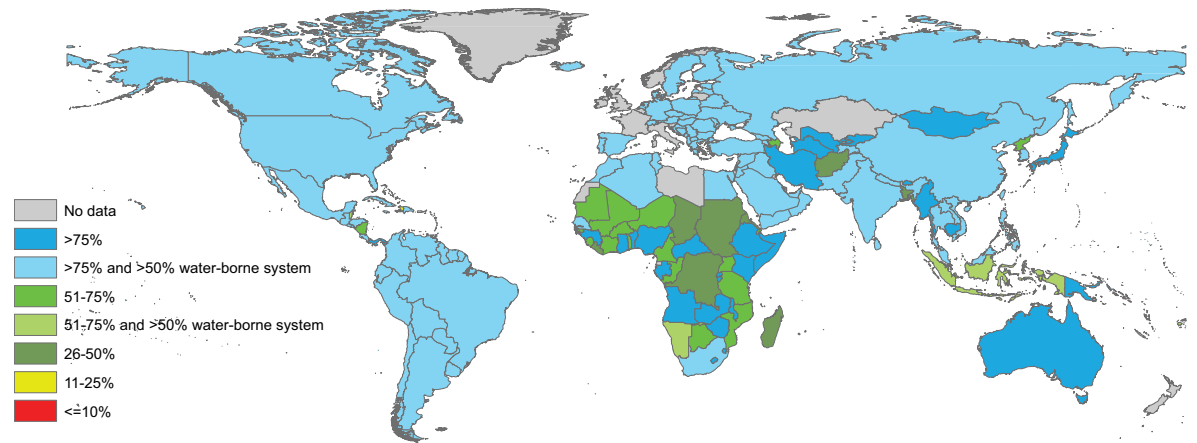
ACCESS TO SANITATION IN URBAN AREAS

Figure 6 shows overall expected coverage with access to urban sanitation by 2020.

Globally most sewerage connections are in urban areas. This contributes to the high water demand of cities and to downstream pollution load.

- The projections for urban sanitation coverage and for rural sanitation coverage (next page) show the importance of household-managed sanitation. Combined with the findings on technology resilience they provide insight into the likely future of sanitation for most of the world's population.

Figure 6
Forecast urban sanitation by 2020



ACCESS TO SANITATION IN RURAL AREAS

Box 4

Terminology

Sewerage refers to a system of flush toilets connected to a network of underground *sewers* that carry *sewage* away from homes to be discharged into the environment, preferably after sewage treatment. *Flush toilets* can alternatively discharge into *septic tanks* or *cesspits*. The waste is then managed locally. *Conventional sewerage* has exacting engineering requirements and is costly. *Modified sewerage* refers to a range of simplified options (such as “small bore”, “shallow” and “condominial” sewerage), typically of lower cost and functioning with lesser flows. These options have been developed to accelerate access especially in the developing world.

Figure 7 shows overall expected coverage with access to urban sanitation by 2020.

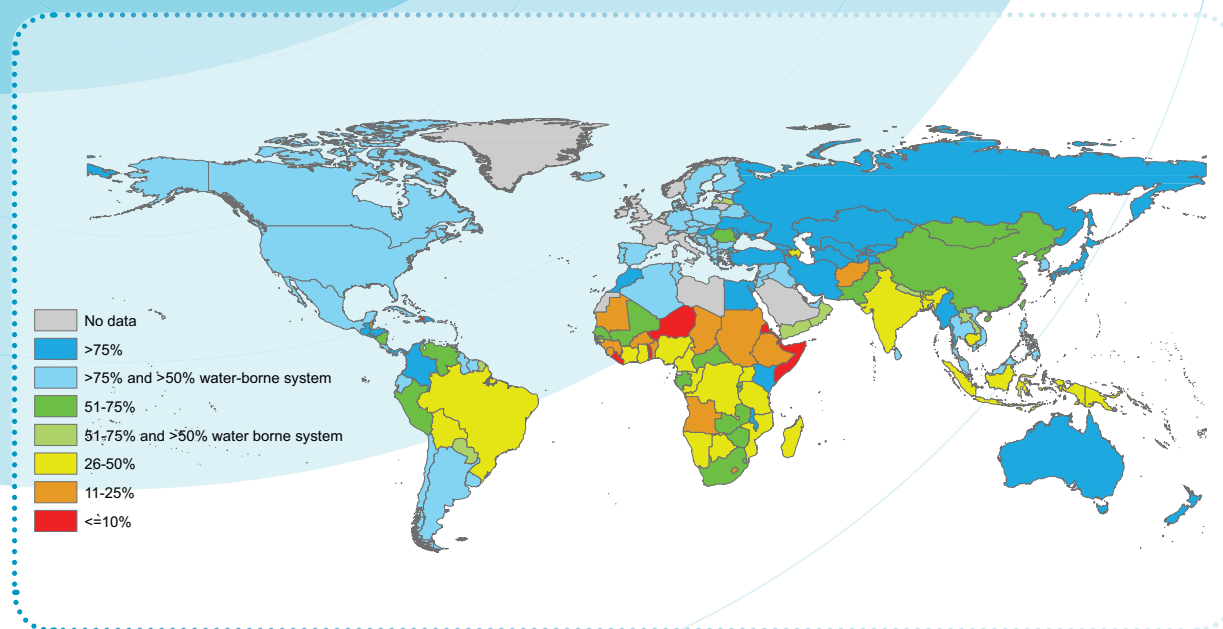
The majority of rural households are likely to rely on different forms of pit latrines, including those which use very low volumes of water. Africa and South Asia are predicted to continue to have significant deficits in coverage by 2020.

Overall conclusions on sanitation

- Latrines of various types are predicted to make up the bulk of sanitation coverage in Africa, and in South, South-east and East Asia.

- Coverage with sewerage (Box 4) is expected to remain relatively low in Africa, and in South, South-east and East Asia until 2020, with most countries having less than 25% coverage.
- In a few already dry countries, sewerage is expected to account for up to 50% of sanitation coverage by 2020, which will place an additional strain on existing water resources.
- Development of sewage *treatment* lags behind extension of sewerage *connection*, and this is expected to continue. Lack of sewage treatment has significant adverse impacts for health and environment, which will be aggravated by climate change if this increases flooding of sewers and overloading of treatment facilities.

Figure 7
Forecast rural sanitation by 2020



RESILIENCE OF DRINKING-WATER AND SANITATION¹

Technology and *management* interact with local circumstances such as water availability and demand to determine the vulnerability and adaptive capacity of water supply and sanitation services. For both water supply and sanitation, technologies were categorized according to their climate change resilience, taking account of both *vulnerability* to climate changes (determined by engineering and environment) and *adaptive capacity* (ability to be adjusted or managed so as to cope in response to different climate conditions). This categorization was based on information from published literature, a series of semi-structured interviews and a web-facilitated questionnaire survey. More research is required to further refine these categories, and to take account of multiple source use.

Drinking-water technologies

There are a wide range of potential climate change impacts on water supply technologies, including flood damage to infrastructure, increased contamination, deteriorating water quality, increased treatment requirements and reduced availability. The technologies considered “improved” under the WHO-UNICEF Joint Monitoring Programme on Water Supply and Sanitation (JMP) were categorized with respect to their resilience to climate change (Table 1).

Table 1

Resilience of water technology to climate change: applicability by 2030

Category 1: Potentially resilient to all expected climate changes	Utility piped water supply Tubewells
Category 2: Potentially resilient to most of expected climate changes	Protected springs Small piped systems
Category 3: Potentially resilient to only restricted number of climate changes	Dug wells Rainwater harvesting
Technologies categorized by JMP as “not improved drinking-water sources”	Unprotected dug wells Unprotected springs Carts with small tank or drum Surface water (rivers, dams, lakes, ponds, streams, canals, irrigation channels) Bottled water

Shallow groundwater systems, roof rainwater harvesting and some surface waters are vulnerable to extended dry periods. It is less likely that impacts will be felt in the mediumterm in deep or old aquifers that have long recharge times.

Piped distribution networks are typically vulnerable to contamination and will be at increased risk where more frequent flooding occurs. In drying environments, piped water supplies may become more intermittent unless resource management measures conserve drinking-water sources.

Tubewells are the most resilient of these technologies; protected springs and small piped supplies have resilience to some climate changes; and dug wells and rainwater harvesting are resilient only to a few climate changes. Existing climate variability already represents a significant problem.

Key finding: All drinking-water technologies will be vulnerable to climate change and all have some adaptive potential.

¹ The vulnerability and adaptive capacity of technologies and management approaches was reviewed by the Robens Centre for Public and Environmental Health, University of Surrey, UK, using information from the published literature, a series of semi-structured interviews and a web-facilitated questionnaire survey (see report 2 on the accompanying CD-ROM).

DRINKING-WATER MANAGEMENT

Key findings:

- *Utility managed water supplies typically have very high potential resilience and adaptive capacity but may have low actual resilience and little implemented adaptation.*
- *Small-community water supply is highly vulnerable to climate change.*

Knowledge gaps:

- *While there is evidence to generalize which technologies are more and less likely to be climate change resilient in a given region, we lack tools to assess the climate change resilience of a technology in a given specific location. Developing such tools is a priority*
- *The effectiveness of simple adaptations, such as raising tubewells to protect against contamination from flooding, remains inadequately understood.*

Urban utility-managed water supply

Utility supplies are intrinsically vulnerable because they are often large and complex. However, in well-run utility supplies, human capital in the form of trained staff, and financial capital to invest in upgrading technology and new infrastructure, make them *potentially* highly resilient to climate change. Many supplies are not resilient in practice because their resilience is reduced by factors such as excessive leakage or intermittent supply.

In the 2007 floods in Gloucester, England, the flooding of the Mythe pumping station resulted in the entire supply to hundreds of thousands of people being interrupted.

Small-community water supply

Direct management of drinking-water supplies by households and communities is common in small communities worldwide. Inadequate operation and maintenance cause frequent failures and contamination. Climate change impacts will adversely affect this already substandard situation by increasing the range and severity of challenges to system management.



SANITATION TECHNOLOGIES

The effects of climate impacts on sanitation may be direct – where water is an essential part of the technology process (e.g. sewerage) – or indirect – where the capacity of the environment to absorb or reduce the adverse effects of wastes is changed.

Sanitation technologies considered “improved” under the JMP were categorized on the basis of their resilience to climate change.

Table 2

Resilience of sanitation technology to climate change: applicability by 2020

Category 1: Potentially resilient to all expected climate changes	Pit latrines Low-flush septic systems
Category 2: Potentially resilient to most of expected climate changes	High-volume septic systems Conventional and modified sewerage
Technologies categorized by JMP as “not improved sanitation”	Latrines without a slab or platform Hanging latrines

Where precipitation levels decline, sewerage systems may become more difficult to operate and maintain. This will be a particular problem for conventional sewerage with its relatively high water requirements. Further problems may also arise from the reduced capacity of water resources to absorb and dilute pollution, which will increase the performance requirements, and hence the cost and potentially the carbon footprint, of wastewater treatment. Sewers are also at risk from flooding damage. Where sewers also carry stormwater, increased flooding will result in widespread contamination, overwhelm treatment facilities and increase public health risks.

Pit latrines as a group of technologies are resilient, because different designs allow adaptation to changing climate. Individual facilities may, however, not be resilient. Where groundwater levels rise, pollution from pit latrines may become more difficult to control.

Key findings:

- All sanitation technologies will be vulnerable to climate change and all have some adaptive capacity.
- Sewerage, widely perceived as the “gold standard” sanitation technology, is only resilient to climate change in some scenarios. Modified sewerage is more climate resilient than conventional sewerage.

Knowledge gap:

- There is enough evidence to arrive at a general idea of which technologies are more and less likely to be resilient to climate change in a given region. But we lack tools to assess the climate change resilience of a technology in a given specific location – developing such tools is a priority.



SANITATION MANAGEMENT



Key finding: For both urban and rural areas, the resilience of household-managed sanitation, combined with projections of sanitation coverage (see Figures 6 and 7 on pages 13 and 14), highlight the ongoing importance of household-managed sanitation and the likely future of sanitation for most of the world's population.

Knowledge gap: There is a lack of information on which technologies and what type of management will be resilient to climate change in specific circumstances. This knowledge will be critical in reviewing programming and operations to assess and increase the achievement of resilience of climate change.

Household-managed sanitation

Overall an estimated 34% of the world's population have a sewer connection, but for many of the world's population sanitation is managed by the household and is provided by one of various forms of improved latrine (an estimated 34%).

Household-managed sanitation has the *potential* to be highly resilient to climate change. However, achieving resilience requires: a demand-driven approach; provision of guidance; and a supportive policy environment. With increased rainfall, household-managed sanitation may add to local groundwater contamination.

Utility-managed sanitation

Utility-managed sanitation worldwide is dominated by sewerage. It is likely that utility management of centralized sanitation systems has high underlying resilience (as is also seen for utility-managed drinking-water). However, the dominant technology – sewerage – is resilient only in some climate scenarios, and this lower technology resilience determines the actual resilience of utility-managed sanitation.



POLICY IMPLICATIONS

Failure to achieve climate change resilience in water supply and sanitation will have serious public health consequences as water quality deteriorates, water quantity becomes less certain and sanitation systems cause environmental contamination. Achieving resilience will have significant policy implications.

Key conclusion 2. Major changes in policy and planning are needed if ongoing and future investments are not to be wasted.

Comprehensive policies needed for water resources management

Drinking-water supply accounts for around 15% of water use worldwide. The reality of ever-increasing multiple demands on finite water resources calls for integrated management with transparent allocation of water and necessary trade-offs between different uses.

Water policies alone, however, are unlikely to be sufficient to secure climate change resilience. Energy policies, for example, will have an important impact. Subsidized energy is already responsible for over-abstraction of groundwater in parts of Asia and central America.

Intersectoral management of water resources

Success in ensuring a sufficient quantity of water for household purposes (“drinking-water”) will depend significantly on success in managing competing demands and multiple pressures on available resources. Integrated water resources management (IWRM) provides an approach to assessing and negotiating agreement among competing demands. There is an urgent need for drinking-water and sanitation to be fully reflected in IWRM policy and practice. In some areas, however, drinking-water and sanitation professionals have engaged little with IWRM.

In addition to harmonizing the water use policies of the various sectors drawing on limited water resources, the formulation of a national policy aimed at promoting intersectoral collaboration will enhance capacities to deal with added stress from climate change.



POLICY IMPLICATIONS



Water storage

Water storage through reservoirs and natural infrastructure provides intra-seasonal averaging of water availability. Water storage also contributes to increasing climate resilience by contributing to the control of flooding. Reservoirs may also be used to sustain availability of water from one year to the next, but this support to managing variability may be compromised by future climate changes. To complicate matters, large man-made reservoirs may have repercussions for local weather patterns. There is a need to greatly improve both natural and artificial water storage, with an emphasis on smaller and more dispersed infrastructure.

Aquifers containing large volumes of water can buffer changes in water availability by providing year-to-year storage capacity. There is, however, a risk of over-exploitation, and climate change will increase the need for effective groundwater management to meet the demands of multisectoral users. Artificial groundwater recharge is increasingly used as a means of storage, with the advantage of reduced evaporative losses and a greater year-to-year storage capacity in some settings. Using groundwater as a store of water is often considered the best adaptation option, but is constrained by generally limited knowledge of groundwater availability. Policies to improve groundwater assessment, management and monitoring are therefore urgently needed.

This must go hand in hand, however, with improved management of services to reduce unaccounted-for water and to manage demand, if access is to be extended to unserved populations while maintaining supplies to those already served.

Increasing available resources

Desalination of coastal water or brackish surface or groundwater is used, extensively in some regions, to supplement insufficient freshwater sources. There have been significant developments in understanding good desalination practice and in decreasing energy demand. Nevertheless, desalination remains an energy-intensive process and therefore has a significant carbon footprint. Policies for its future use need to take account of this impact, and further research is required to increase deployment of desalination technologies driven by low-carbon energy.

DECENTRALIZATION POLICIES

The level of decentralization critically determines how services will be delivered. The impact of decentralization policies on drinking-water and sanitation services, on water quality and on multiple use patterns will need to be analysed in the context of climate change. The need for policy adjustments is to be ascertained. There are two important aspects: institutional and physical.

Institutional centralization of drinking-water and sanitation services.

Administration and management of services remain centralized, although the physical supply systems may be either centralized or decentralized.

- Some benefits of institutional centralization in ensuring high technical competence and economies of scale in administration will contribute greatly to adaptive capacity.
- Extreme institutional decentralization – as in rural community-managed systems – is associated with a high rate of failure. This can be reduced by ensuring access to (centralized) technical and management support which is likely to be critical in increasing resilience.

Physical centralization of drinking-water and sanitation services.

Integrated piped systems link together multiple communities and possibly multiple sources. The climate change resilience of centralized or integrated systems typically varies.

- Systems reliant on a single water source to provide water to large populations or multiple communities are the most vulnerable.
- Systems which link multiple communities and multiple sources spread risk and are more resilient, since failure, deficiency or flood damage to one source or component are unlikely to cause catastrophic failure.
- Extremely large systems may transport water over considerable distances, which may appear to be an appropriate adaptation. There is, however, limited experience with long-range bulk transport. It is costly and may suffer leakage and water quality deterioration. Since climate change predictions (see Figure 3) typically imply large-area trends, bulk transfer systems would need to be extremely large to compensate for water scarcity in one area by transferring water from another.

Knowledge gap: There is too little accrued knowledge about bulk transport of water to adequately assess the role it could play in climate change adaptation.



WATER POLICY IMPLICATIONS: SERVICE LEVEL



Key findings:

- *Maintaining and accelerating the trend towards household-level water access, in a manner that is resilient to climate change, is a development priority.*
- *The urgency of ensuring that all people have access to at least a simple improved source, alongside the low resilience of both community management and some community source technologies, constitutes a critical development challenge.*

Knowledge gap:

- *There is inadequate knowledge of the groundwater resources in Africa and their sustainable yield to enable an understanding of the feasibility and sustainability of technology options.*

Household piped water was used by just over half the global population in 2006 and is projected to increase slightly to 55% by 2020. This trend is highly desirable for its health, social and economic benefits (see Box 5) and because utility-managed systems are expected to be more resilient to climate change.

There is a need for a policy shift worldwide towards accelerating progress in coverage with an at-house water supply. This policy shift should be achieved by national and local drinking-water and sanitation authorities as well as by the bilateral and multilateral assistance agencies.

Dense coverage with tubewells (one per household, on-plot) has been little attempted outside South Asia, where such wells are better maintained than community facilities. To use this approach elsewhere will require: a better understanding of groundwater availability; policies promoting health impact assessment (focusing on natural groundwater contaminants); and overcoming the recognized problems of community management.

Large rural populations in some regions (both developing and developed) will rely on community-managed sources and systems for the foreseeable future. Given the very high vulnerability of community-managed systems, there is an urgent need to increase efforts to provide improved systems and to support community management.

Box 5

Benefits of an at-house water supply

Much greater health benefits accrue where people have a water supply on their household plot rather than having to walk to a shared source. Health benefits derive from hygiene facilitated by greater water use. Also, more time is available for child care and income earning activities that translate into an increased buying power for medicine, treatment and other preventive measures.

On-plot water supply typically means that each person will use about 50 liters per day. An on-plot source can be as simple as a single tap in a yard. This increases demand on water resources and there must be functional drainage to prevent the creation of mosquito breeding sites.

SANITATION POLICY IMPLICATIONS

Policy interventions that need emphasis include those to promote development of sewerage technologies with greater climate resilience under local circumstances.

Sanitation for large, densely populated, urban areas: sewerage

Effective functioning of sewerage systems normally requires a reliable water input. Low flows can cause blockage and malfunctioning. The dependability of water for sewerage is deteriorating in some regions under the combined influence of climate change and other pressures. Modified sewerage systems typically use lower volumes of water and are less prone to blockage if flows are unreliable – and so are more climate resilient.

Separation of stormwater from sewage is highly advisable to minimize the risk of overwhelming collection systems and treatment facilities, and the associated pollution impacts. This risk is increasing because of the greater likelihood of flooding, associated with climate change.

Key sanitation policy objectives in the urban setting should be greater use of modified sewerage systems in many low- and middle-income countries, and the separation of stormwater and sewage systems.

The cost of controlling London's storm overflows (which discharge 32 million tonnes of sewage into the river Thames every year) by building a large receptor tunnel under the river Thames has been estimated to be more than £2 billion. Separating sewage and stormwater in the centuries old system is considered unrealistic.

Sewage treatment lags far behind sewerage coverage, leading to significant pollution problems. Decentralized wastewater treatment systems often have lower operating requirements and costs, but may be vulnerable to flooding

Knowledge gap: *There is a deficiency in the technology options available for sewerage. For some urban areas, there are no proven alternatives to costly and water-intensive waterborne sewerage.*



IMPLICATIONS FOR PROGRAMMING AND OPERATIONS



Key finding: Acting to increase climate change resilience and avert future problems is preferable to dealing with the adverse impacts when they occur, and is likely to be cost-effective in both developing and developed regions.

Key conclusion 3. Potential adaptive capacity is high but rarely achieved. Resilience needs to be integrated into drinking-water and sanitation management to cope with present climate variability. It will be critical in controlling adverse impacts of future variability.

Because of inherent uncertainties in climate change forecasting, planning needs to be strategic, allowing for flexible responsiveness working towards increasing resilience. Even though large parts of the world are unlikely to see major changes in precipitation by 2030, the uncertainty means that climate impact assessments are needed for all water and sanitation utilities and programmes.

In Sudan, the assessment of available water resources was done late in the process of planning and installing the provision of water supplies to camps of displaced people. This is now raising significant issues regarding the sustainability of water supplies.

Climate change assessments

Systematic assessments of the climate change resilience of all utilities and of rural water and sanitation programmes are needed. An approach similar to that of Water Safety Plans could be used to assess and plan for potential impacts related to climate change, as well as other hazardous events.

For large systems this will require long-term – 50 year or longer – time horizons and increasing use of scenario-based planning. For smaller systems and programmes supporting household facilities, time horizons may be shorter.

Safety plans resulting from climate change assessments should address both adaptation to and mitigation of climate change. Water and sanitation services produce greenhouse gases, and system improvements can support the mitigation of climate change.

Technology changes arising from assessments should be based on climate performance in addition to other environmental, social and cost concerns. Technologies resilient only to some climate changes should be promoted only where local assessment demonstrates resilience or where local conditions dictate that more resilient technologies cannot be used. Social resistance, technical constraints and cost issues are the three important categories of obstacles to the use of resilient technologies. The technology resilience categories in Tables 3 (page 26) and 4 (page 28) can assist in technology selection. In all cases, using current best practice will go some way to improving climate resilience.

SYSTEMATIC INCORPORATION OF CLIMATE CHANGE PLANNING IN DRINKING-WATER SYSTEM ASSESSMENT AND MANAGEMENT

Most of the world's population already receives piped drinking-water from a utility and this proportion is increasing. Utility water supplies have high *potential* resilience but for many actual resilience remains to be achieved. Becoming climate resilient means addressing utility operational performance.

- Reducing leakage is likely to be important and critical in areas of declining water availability, both for water economy and to reduce contamination. It also contributes to reducing the energy needs and carbon footprint of water supply itself.
- Progressive upgrading should spread risk by exploiting multiple independent sources.
- Over-exploiting groundwater resources in response to scarcity driven by climate change will undermine sustainability.
- Increasing storage capacity, for example through surface water dams and artificial groundwater recharge, may contribute to resilience.

Preventive management approaches such as Water Safety Plans provide a simple robust framework to make climate resilience assessments, and to

plan progressive adaptation to climate change and concurrent challenges. The process includes defining hazards, assessing risks, and identifying and validating control measures. A preventive approach should lead to management responses and system improvements.

The principal health and development priority for drinking-water is universal access to an improved source and preferably to piped water at home. However, community water sources will remain important for large populations for the foreseeable future.

- Of the commonly used community source technologies, only tubewells appear resilient to most climate changes. This indicates greater care in identifying which technologies should be used and research to improve climate resilience of other technologies.
- Community management of water sources and small supplies is associated with high rates of failure and contamination. Climate change will increase stresses on community management. Successful approaches to support community management should be extended and alternatives sought.

- Very vulnerable technologies, such as dug wells and protected springs in urban environments and where aquifers are vulnerable to contamination should be progressively replaced with more resilient alternatives.

Professionals working on climate change and on drinking-water supply and sanitation will need to strengthen their dialogue and increase their collaboration if an adequate and appropriate response to the challenges of climate change is to be ensured.

The CD-ROM accompanying this booklet includes a set of fact sheets with detailed information on adaptation options for different technologies. These cover particular vulnerabilities and different adaptations for planning, maintenance, monitoring and education.

Knowledge gap: *Experience with artificial groundwater recharge has accumulated but good practice needs to be consolidated and disseminated.*

Key finding: *Water utilities should systematically assess their climate change vulnerability and, where risk is significant, initiate measures to increase resilience.*



Table 3

Conventional sewerage and pit latrines: vulnerability, impacts and adaptation methods

VULNERABILITY	IMPACTS	ADAPTATION METHODS			
		CAPITAL EXPENDITURE	OPERATIONAL EXPENDITURE	MONITORING	SOCIO ECONOMIC TOOLS
Utility piped water supplies – flooding increases					
Water intakes may be left exposed as water levels fall.	Highly turbulent water flows in rivers after heavy rain may damage intakes.	<p>Design water intake to accommodate varying water levels (for example floating booms).</p> <p>Develop groundwater sources where feasible.</p> <p>Design and construct overflows for source reservoirs to prevent failure .</p> <p>Strengthen river intakes to withstand more turbulent flows.</p>	<p>Maintain spillways and channels in good order.</p> <p>Develop, implement and update water safety plans.</p>	Early warning system installed.	<p>Disseminate early warnings.</p> <p>Update and disseminate evacuation procedures.</p> <p>Increase frequency with which emergency procedures are practised.</p>
Tubewells - water availability decreases					
<p>Increased use of viable wells causes increased wear and tear and increased water demand.</p> <p>Damage to the well or borehole increases the risk of contamination entering the water source.</p>	Public health risk from consumption of the water.	Determine the degree of vulnerability by investigating linkages between climate and groundwater, e.g. residence times.	Ensure high levels of maintenance on in-demand wells.	<p>Sanitary survey.</p> <p>Monitor the ability of wells to cope with current droughts.</p>	Implement discussions with other users of aquifer such as irrigation farmers and private well owners to manage the resource cooperatively.

IMPLICATIONS FOR SANITATION PROGRAMMING AND OPERATIONS

Climate change impacts on sanitation relate to both the ability to sustain and extend sanitation services, and the risk of inadequate sanitation causing contamination, especially of drinking-water sources and supplies.

Household-managed sanitation is potentially resilient to climate change, as is the technology most often managed by households – a latrine. This implies that providing supportive guidance and policy is a priority in order to continue and enhance the rate of progress. Such support is essential because, while the management and technology are resilient not every latrine will be resilient in practice.

Where technology selection is demand-driven, there is a need to make sure that information on climate resilience, as well as on cost, social and other concerns, is available in order to ensure more effective decision-making. It is important that the ability of each technology to perform in the current and predicted future climates is assessed and those with the greatest potential to adapt to future climates given greater priority. The technology resilience categories in Tables 2 and 4 can assist in selecting technology.

Direct climate change impacts on sanitation programming and operations

Providing services to the 2.5 billion people who lack access to basic sanitation is a global priority. This needs to be done in a climate-resilient way to ensure that access can be sustained. For on-site systems such as pit latrines, major challenges may exist in preventing the latrines becoming a large pollution risk to groundwater resources used for drinking-water supply.

Pit latrines are projected to be extensively used and are resilient to most climate changes. The different designs for pit latrines make them highly adaptable. There is a need to document the simple adaptations to different climates, and make these designs more widely available.

In drying environments, there will be little impact on latrine functioning and decreasing risks of groundwater pollution. Where the climate gets wetter, adaptations exist to the design to raise latrines, improve the stability of the pit, and reduce pollution risks.

Use of pit latrines increases the risks of contamination of groundwater. Simple risk-based approaches to separating latrines and groundwater sources are effective and should be more widely deployed.

Conventional sewerage will be challenged in drying environments. It will also be under threat where increased extreme rainfall is expected, which may result in physical damage to the system and in environmental contamination if stormwater is combined with sewage. Unconventional sewerage may offer greater resilience because water requirements are lower, and sewerage would not usually be linked to stormwater drainage.





Table 4

Conventional sewerage and pit latrines: vulnerability, impacts and adaptation methods

VULNERABILITY	IMPACTS	ADAPTATION METHODS			
		CAPITAL EXPENDITURE	OPERATIONAL EXPENDITURE	MONITORING	SOCIO ECONOMIC TOOLS
Conventional sewerage – flooding increases					
Infiltration of floodwater into sewer leading to plug flow of pollutants and re-suspension.	Overloading of treatment works. Pollution of water resources downstream. Ingress of silt.	Use sustainable urban drainage systems or separate sewers. Encourage decentralized systems.	Clean sewers regularly. Clean drains regularly especially just before wet season.	Early warning system installed.	Disseminate early warnings. Update and disseminate evacuation procedures. Increase frequency with which emergency procedures are practised.
Pit latrines - increased rainfall causes groundwater levels to rise					
Inundation of the pit from below.	Contamination of groundwater and soil, potentially reaching drinking-water sources.	Provide protected water supply. Consider options: - shallower pits and more frequent emptying; - dry composting latrines; - sewerage.	Regular pumping or emptying of pit latrine (particularly in the urban setting) - link to smaller pit.	Monitor drinking-water quality.	Increase user education and marketing of alternatives.

INTERNATIONAL POLICY IMPLICATIONS

International monitoring of drinking-water and sanitation

Much of the existing infrastructure and many existing services are not resilient to climate change. The MDG targets (Box 1 on page 7) refer to “sustainable access”. There is significant variation in the resilience to climate change and therefore the sustainability of different technologies.

While resilience to climate change will be site-specific, using the information from Tables 3 and 4 it is possible to generalize about technology resilience by region.

JMP (see Box 3 on page 10) does not take resilience to possible climate change impacts into account. If this were to be done, the current figures for coverage would need to be revised downward and might show that the world is off-track to meet both the drinking-water and sanitation components of MDG 7.

Table 5

Indicative list of technologies suitable by region

REGION	CATEGORY 1	CATEGORY 2	CATEGORY 3
South-western Africa	All appropriate	Protected springs, community-managed piped, small-bore and shallow sewers appropriate Conventional sewers and septic tanks less appropriate	Dug well use will require local information Household roof-catchment harvesting only as supplementary
Central and East Africa	All appropriate	All appropriate, but additional safeguards against flooding required	Rainwater appropriate Dug well not appropriate
Rest of sub-Saharan Africa	All appropriate	All appropriate	Appropriate, provided local conditions permit
Northern Africa	All appropriate	Protected springs, community-managed piped and unconventional sewers appropriate Conventional sewers and high-volume septic systems not appropriate	Dug wells appropriate where local conditions permit Rainwater not appropriate
South Asia	All appropriate	All appropriate, but additional safeguards against flooding required	Rainwater appropriate Dug wells not appropriate
SE Asia	All appropriate	All appropriate, but additional safeguards against flooding required	Rainwater appropriate Dug wells not appropriate
Central Asia	All appropriate	All appropriate	All appropriate
East Asia	All appropriate	All appropriate, but additional safeguards against flooding required	Rainwater appropriate Dug wells not appropriate
Central America	All appropriate	All appropriate, but additional safeguards against flooding required	Rainwater appropriate Dug wells not appropriate
NE South America,	All appropriate	Protected springs, community-managed piped and unconventional sewers appropriate Conventional sewers and septic tanks not appropriate	May be appropriate, but will face long-term drying trends
Rest of South America	All appropriate	All appropriate	All appropriate
Eastern Mediterranean and West Asia	All appropriate	Water supplies and unconventional sewers appropriate Conventional sewers and septic tanks not appropriate	Dug wells appropriate Rainwater not appropriate
Pacific Islands	All appropriate	Appropriate depending on local conditions, but sewerage and septic tanks unlikely to be appropriate	All feasible depending on local conditions



IMPACT ON ACHIEVING THE MILLENNIUM DEVELOPMENT GOALS

Climate change impacts on drinking-water and sanitation coverage must be considered in the context of other conventional challenges such as sustaining existing services, increasing investment and improving governance. In many cases, the conventional challenges will be much greater than the challenge from climate change. Nevertheless, addressing climate resilience is necessary if the progress made so far towards achieving the MDG targets is to be safeguarded.

Formulating targets post-2015

A new set of targets will need to be agreed for the post-2015 period, to continue the momentum to providing access to safe drinking-water and basic sanitation for those millions of people who will continue to lack it, and to safeguard access for those who have it. Given the anticipated changes in climate, it will be essential for any monitoring system measuring progress towards achieving these new targets to include resilience indicators.



REGIONAL ISSUES AND HOT SPOTS

Key conclusion 4. Although some of the climate trends at regional level are uncertain, there is sufficient knowledge to inform urgent and prudent changes in policy and planning in most regions.

This study highlights a number of regional concerns: areas where changes in climate are likely to have significant implications for drinking-water and sanitation. It is in these areas that efforts to build adaptive capacity in technology and planning are most urgently required.

A more comprehensive analysis, beyond the scope of this study, would take account also of status and trends in other factors creating demands on water resources, especially agriculture and energy generation, industry and ecological needs, as well as status and trends in responses to these combined demands and stressors, such as increasing storage capacities and demand management within each use sector.

Two key areas have been identified where climate changes may represent the most significant problems in the medium term:

- drying environments: southern Africa, North Africa, Central America and north-eastern South America, and the eastern Mediterranean
- environments that may experience more flooding: South Asia, parts of east Asia, and parts of central and east Africa.

Coastal areas represent a general potential hot spot

In addition to these areas, coastal areas are likely to face problems around the world. A quarter of the world's population live in coastal areas and many are already facing water problems, as there are limited water resources and high demands from the existing population.

Where saline intrusion is expected to be a problem, a number of alternative technologies could be considered. In some countries, such as Bangladesh, deeper confined aquifers exist that offer a safe source of water. Experience shows that this requires priority to be given to safeguarding the use of this resource for drinking-water, because abstraction for agriculture is already leading to falling water tables. In other areas, use of rainwater harvesting (where climate changes suggest this will deliver sufficient water), desalination or blending with low salinity waters may need to be considered.

AFRICA SOUTH OF THE SAHARA

Declining average rainfall is forecast for southern Africa, which is already relatively dry. Southern Africa also has significant rates of piped water supply and sewerage. Without better demand management and a reduction of unaccounted-for water, the region may encounter significant problems in meeting household water demand, particularly in urban areas. In rural areas, the problems may be less immediately acute, but water sources for domestic supply will need to be protected, and improved practices for

water resources management will need to be put in place.

Throughout the rest of Africa south of the Sahara, forecasts suggest either no change or increases in rainfall. Combined with projections predicting only limited access to household-level water supply and sewerage (typically less than 50% piped water supply and less than 10% sewerage), this suggests that water quantity may not be a regional concern, although national and local problems may occur.

Much of Africa south of the Sahara is underlain by basement fracture aquifers which can supply only low volumes of water. Developing multiple small aquifers for relatively low-yielding household tubewells may be more climate resilient than relying on development of a smaller number of aquifers to supply piped systems. But policy and decision-making about these options will have to rely on much more information and a greater understanding of the available water resources.

Other research has suggested that the areas at most risk from reduced rainfall are likely to be those with between 200 and 500 mm of rainfall – a strip of the Sahel and parts of south-western Africa. The Sahelian north band is projected to rely heavily on protected wells, particularly for rural coverage; the southern band to rely on piped water. In parts of Central and East Africa likely to experience more flooding, the major risks are associated with damage to water and sanitation infrastructure, and contamination. Many of these countries are poor and rely on point-sources of water. A shift away from dug wells to tubewells with handpumps is likely to be essential.



NORTH AFRICA AND THE EASTERN MEDITERRANEAN

Declining average rainfall is forecast for North Africa and the eastern Mediterranean, which are both already relatively dry. Combined with high rates of piped water and sewerage, this suggests a need for significant improvements in the efficiency of water use, and better management of water resources to prevent unsustainably high rates of groundwater abstraction. This is likely to affect urban areas more seriously than rural areas, but in the long term similar improvements will be needed for rural water supplies and sanitation.

Reserves of fossil water in North Africa represent a sufficient supply for some decades. A challenge may well be to conserve these waters for domestic use in the face of competing demands.

Desalination is more common in the eastern Mediterranean region than elsewhere and this is likely to continue, although changes in energy cost and availability would have a large impact. Desalination may also be a source of additional greenhouse gas emissions. Thus, careful consideration will be needed before embarking on more widespread use of desalination technologies.



SOUTH ASIA

Increasing average precipitation and more intense five-day wet weather events are forecast for this region, making flooding more likely. Flooding challenges most types of water supply, but in particular dug wells, which are used in arsenic-affected areas of Bangladesh and India, for example.

High mountain regions are warming faster than the global average. This affects drinking-water supplies that depend on rivers and lakes where glacial melt water forms a significant part of the low-season flow. The regions supplied by water from the western arm of the Himalaya are dry, and glacier melt water contributes up to 70% of the dry season flow of some rivers. The forecasts in the present study and the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* point to a likely increase in rainfall (probably within the existing monsoon) in the north-western Indian sub-continent. This suggests that increased water storage should be able to offset some of the problems resulting from a loss of glacial melt water.



CENTRAL AND NORTHERN SOUTH AMERICA

In Central America and north-eastern South America, there are indications of an overall drying of the climate. This is combined with a predicted increase in piped water coverage, which is already over 75%. This region is likely to start to face significant problems with drought, and urgent thinking is needed on how water supply for domestic use will be secured and risks managed, in order to have clear processes in place for water allocation.



CRITICAL KNOWLEDGE GAPS

Key conclusion 5. There are important gaps in our knowledge that already or soon will impede effective action. Targeted research is urgently needed to fill gaps in technology and basic information, to develop simple tools, and to provide regional information on climate change.

Gaps in basic information

There are significant gaps in the basic information that we require to understand the situation and to plan for its improvement. Examples include the following.

- The water demand from simple non-piped household-level access to drinking-water remains unknown. Knowledge of this demand would facilitate assessment of the feasibility of implementing policies favouring higher drinking-water service levels, which would in turn benefit health and development.
- The potential impact of bulk transport on ensuring access to adequate quantities of drinking-water where and when needed require elucidation.
- Greenhouse gas emissions from sanitation alternatives need to be estimated.

- The social and economic aspects of household-managed sanitation remain unstudied.

Water demand for sewerage in large urban centres can be substantial. Although there has been some experience, in cities, with dry sanitation or sanitation that uses very little water, there remains much more to be learned about how simple and low-cost technologies can be used without posing an unacceptable risk of contamination. The logical need for such technologies is self-evident and represents a major technology gap.

Technology gaps, and research and development needs

There are important technology research and development (R&D) needs which are likely to slow the pace of adaptation and reduce the capacity to strengthen resilience to climate change.

- Waterborne sewerage has only moderate adaptive capacity and yet serves as the current technology “gold standard”. Attractive and sustainable alternatives are urgently required. Ideally such alternatives would leapfrog over waterborne sewerage technology with all its limitations (principally

cost, water demand and environmental pollution burden) to provide a better alternative than that aspired to today.

- Rapid developments in sensors and communication technologies and services have not yet yielded their potential benefits in making more, better quality information available where needed in a timely way. Again, leapfrog opportunities may exist.
- Over the course of decades, the trend towards household on-plot water will secure health, social and economic benefits for large populations. With the exception of utility-provided supply, the means to extend this service level have been little explored. The potential for household-level supply, for example, requires active exploration.
- Community management of community sources and small supplies is associated with high rates of failure and contamination. Climate change will increase stresses on community management. Efforts to support community management should be critically evaluated and alternatives sought.

THE NEED TO CONSOLIDATE EXPERIENCE AND LESSONS LEARNED

Simple tools based on solid experience are needed but lacking in the following areas:

- Simple procedures are needed for rapid assessment of the vulnerability of a utility to climate change.
- Good practice should be followed in artificial groundwater recharge.
- In order to facilitate rapid and widespread assessment, and progressive adaptation to increase resilience, simple guidance and support tools are needed, but they are not yet available. Progress is hindered by limited experience and insufficient access to lessons learned. Development of scenario-based assessment and planning tools, based on credible outcomes from predicted climate change, would be an important contribution.

The need to understand the water resources base

- There is a fundamental lack of understanding of the water resources base, but such an understanding is needed to inform planning.
- Demands for water from other sectors, potential economies and fundamental limits to efficiency are inadequately understood. This impedes implementation of water allocation policies that would safeguard water sources for domestic supply within wider benefit-sharing, supporting both health and development through multiple sectors.

- There is a lack of hydrological and hydrogeological information in many developing countries, making forward planning of new water supplies extremely uncertain. This critical gap needs to be filled urgently.
- There is great uncertainty about the impact that climate change will have on groundwater. This in part reflects the limited knowledge on groundwater resources, their recharge and sustainable yields. In part it also reflects an inadequate understanding of the impact of climate change on recharge, which is likely to be dependent on specific circumstances.
- There is a lack of understanding of the consequences of increasing intensification of rainfall.

In South Asia, there are still key knowledge gaps about some of the older aquifers, which represent critical strategic resources. For instance, the older aquifers in the Bengal basin could be more widely developed and may need to be, given likely changes in surface water flows and the widespread presence of arsenic in shallow groundwater.

FURTHER READING

Bartram J et al. (2009). *Water safety plan manual: a step-by-step guide for drinking-water suppliers*. Geneva, World Health Organization.

Bates BC et al., eds (2008). *Climate change and water. Technical paper of the Intergovernmental Panel on Climate Change*. Geneva, Intergovernmental Panel on Climate Change.

Howard G, Bartram J (2003). *Domestic water quantity, service level and health*.

Geneva, World Health Organization (WHO/SDE/WSH/03.02).

Parry ML et al. eds (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, Cambridge University Press.

WHO (2009). *Protecting Health From Climate Change: Global Research Priorities*, Geneva, World Health Organization.

(<http://www.who.int/globalchange/publications/9789241598187/en>)

WHO, UNICEF (2008). *Joint Monitoring Programme: progress on drinking-water and sanitation – special focus on sanitation*. Geneva, World Health Organization (http://www.who.int/water_sanitation_health/monitoring/jmp2008.pdf).

WHO (2004). *Guidelines for drinking-water quality*, 3rd ed. Geneva, World Health Organization.



ACKNOWLEDGEMENTS



This booklet and the associated report and three individual study reports are the output of cooperation between the United Kingdom Department for International Development (DFID) and WHO. The work was conceived and managed by Guy Howard (Water & Environment Adviser, Climate & Environment Group, DFID) and Jamie Bartram (former Coordinator, Water, Sanitation, Hygiene and Health, and now Director of the Global Water Institute, University of North Carolina) who co-authored this summary and the associated report.

Thanks are due to the study teams that produced the three background reports: Richard Graham and Anca Brookshaw of Met Office Hadley Centre; and Stephen Pedley, Kathy Pond and Katrina Charles of the Robens Centre for Public and Environmental Health, University of Surrey.

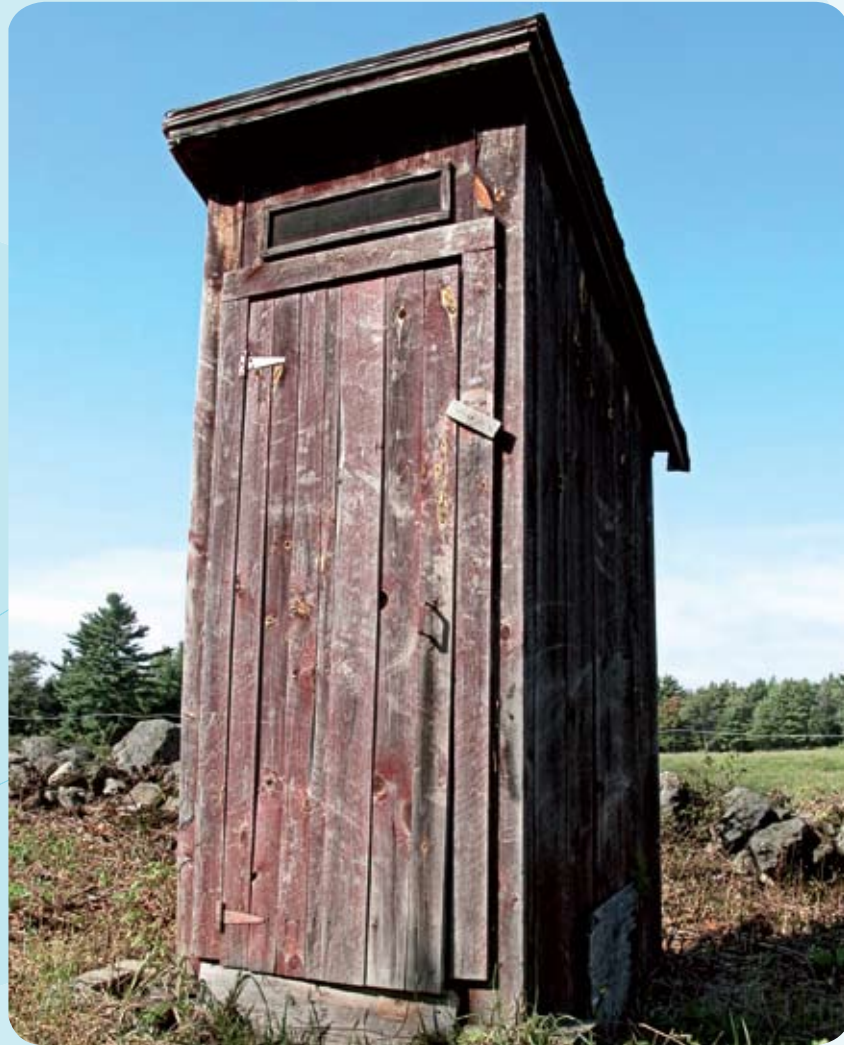
In WHO, Rifat Hossain and Celie Manuel contributed to the statistical analysis. Robert Bos (current Coordinator, Water, Sanitation, Hygiene and Health) managed the final production process. Angela Haden edited the text in her usual efficient way.

The quality of this summary and the associated report owes much to individuals who commented on earlier drafts: Feroze Ahmed, Vahid Alavian, Charles Batchelor, Jay Bhagwan, Clarissa Brocklehurst, Declan Conway, Andy Krumins, Andreas Kuck, Roberto Lenton, Alan Macdonald, Stef Smits, and Renaat de Sutter.

Thanks are also due to the following individuals who participated in a working session to define climate risks and technology vulnerabilities and adaptations: Chee Keong Chew, Barbara Evans, Barry Lloyd, Brian Read, Beth Scott, Mike Smith, David Sutherland, and Richard Taylor.

The CD-ROM accompanying this booklet contains:

- the full technical report on which this summary is based;
- the detailed report of the climate change projection study;
- the detailed report of the technology projection study;
- a detailed review of resilience and adaptive capacity, including a series of technology-by-technology fact sheets.



THE GLOBAL CLIMATE IS CHANGING

Drinking-water and sanitation are foundations of public health and development. In developed countries they are largely taken for granted by citizens but carefully regulated by governments. In the developing world they are targets of development policy.

If the widely-anticipated flood and drought consequences of climate change come to pass, then both established water and sanitation services and future gains in access and service quality will be at real risk.

The Vision 2030 Study set out to increase our understanding of what climate changes can be anticipated; how and where they will affect drinking-water and sanitation; what can be done to optimize the technologies and systems that exist to maximize their resilience; and what needs to be done differently to ensure that the services of the future can cope with the climate changes we can anticipate. The study reached five key conclusions:

1. Climate change is widely perceived as a threat rather than an opportunity. There may be significant overall benefits to health and development in adapting to climate change.
2. Major changes in policy and planning are needed if ongoing and future investments are not to be wasted.

3. Potential adaptive capacity is high but rarely achieved. Resilience needs to be integrated into drinking-water and sanitation management to cope with present climate variability. It will be critical in controlling adverse impacts of future variability.
4. Although some of the climate trends at regional level are uncertain, there is sufficient knowledge to inform urgent and prudent changes in policy and planning in most regions.
5. There are important gaps in our knowledge that already or soon will impede effective action. Targeted research is urgently needed to fill gaps in technology and basic information, to develop simple tools, and to provide regional information on climate change.

ISBN 978 92 4 159842 2



9 789241 598422