WWDR4

Overview of Key Messages

FROM THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 4

Managing Water under Uncertainty and Risk

Part 1:

Recognizing the centrality of water and its global dimensions

Access to water is critical to the well-being of people in all domains – personal, familial and social. Water also makes an essential contribution to economic output. It underpins the sound functioning of natural environmental and ecological systems. Many economic sectors compete for finite water resources. Water is the *only* medium through which major global crises (food, energy, health and climate change, as well as economic crises) can be jointly addressed. Explicit trade-offs may need to be made to allocate water to uses which maximize achievable benefits across a number of developmental sectors. This is a critical challenge, but one whose achievement is difficult and complex in practice.

United Nations Educational, Scientific and Cultural Organization
World Water Assessment Programme
UN WATER

Protecting water resources, optimizing their use across these activities, and ensuring an equitable distribution of benefits from water-intensive activities should be at the centre of public policy and regulation. This is true for all levels of water governance: local, regional, river basin and central. Failure to deal strategically with these issues of allocation, resulting in a fragmented approach to water management, will jeopardize future availability and sustainability of water resources and is likely to reduce economic and social welfare below attainable levels.

The task of delivering sufficient quantities of water for social, economic and environmental needs has traditionally been regarded as the responsibility of those directly involved in its extraction, collection and use – the 'water sector'. However, the availability of water throughout the hydrological cycle is influenced by many factors that lie outside the direct control of water authorities. Effective and sustainable management of water resources and allocation requires cooperation and coordination between diverse stakeholders and sectoral 'jurisdictions'.

In future, global water resources are likely to come under increased pressure. The demand for water is growing at the same time as climate change is expected to


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threaten its availability. Water is not confined within political borders. An estimated 148 states have international basins within their territory, and 21 countries lie entirely within them. In addition, about 2 billion people worldwide depend on groundwater supplies, which include 273 transboundary aquifer systems. Multiple and increasing drivers of water use and the uncertainties associated with them are likely to put existing transboundary agreements under stress.

Ultimately, these issues can only be addressed in international forums. The UN Framework Convention on Climate Change (UNFCCC), the Millennium Development Goals (MDGs) and the UN Conference on Sustainable Development (CSD) are particularly important. Under the leadership of member states, their activities need to be supplemented by proper consultation processes to ensure the effective implementation of global policies at country level. Members of the water community have the duty to inform and provide guidance to this process.

Water demand

What drives consumption?

The demand for water originates from four main sources: agriculture, production of energy, industrial uses and human consumption.

Energy and water are intimately connected. All sources of energy and electricity require water in their production processes: the extraction of raw materials, cooling in thermal processes, cleaning processes, cultivation of crops for biofuels, and powering turbines. Energy is itself required to make water resources available for human use and consumption through pumping, transportation, treatment, desalination and irrigation.

Already, over 1 billion people lack access to electricity and other clean sources of energy. Increases in demand due to population growth and increasing economic activity are expected to cause a surge of energy consumption, particularly in non-OECD countries.

There is a direct link between water and food production. Production of crops and livestock is water-intensive and agriculture accounts for 70% of all water *withdrawn* by the combined agriculture, municipal and industrial (including energy) sectors. The booming demand for livestock products in particular is increasing the demand for water. It is also affecting water quality, which in turn reduces availability. Responsible agricultural water management will make a major contribution to future global water security.

The global demand for food is expected increase by 70% by 2050. However, predicting future water demand in agricultural uses is fraught with uncertainty, depending on the methodologies and assumptions adopted. Demand is influenced by population levels, the type of food in demand, and quantities consumed. Crop types, yields and efficiency of agricultural production also affect the quantities of water required, while climatic variations add to the uncertainties.

Best estimates of future global agricultural water consumption (including both rainfed and irrigated agriculture) are of an increase of about 19% by 2050. Much of the increase in irrigation water consumption will be in regions already suffering from water scarcity.

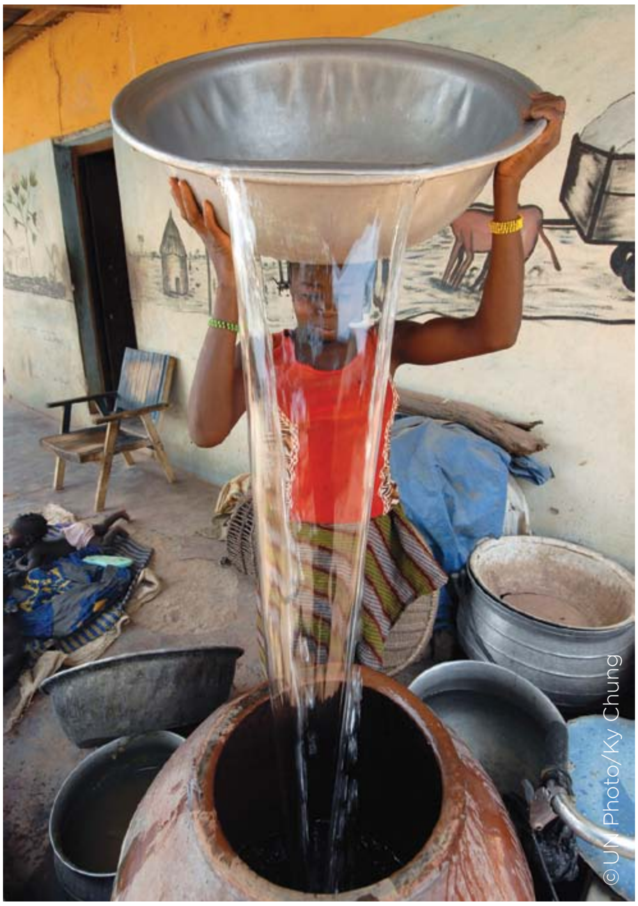
Water is an integral part of many industrial processes and increasing demand for water for industrial uses will result from increasing economic activity.

Regarding human consumption, the main source of demand comes from urban communities requiring water for drinking, sanitation and drainage. The urban population of the world is forecast to grow to 6.3 billion people in 2050 from 3.4 billion in 2009, representing both population growth and net migration from countryside to town. There is already a backlog of unserved urban populations, and the number of people in cities who lack access to improved water supply and sanitation is estimated to have grown some 20% since the MDGs were established.

The water resource: Variability, vulnerability and uncertainty

Understanding the spatial and temporal distribution and movement of water is crucial for efficient water resources management. Freshwater supplies are erratically distributed, geographically and over time. There is considerable variability between arid and humid climates and between wet and dry seasons. The distribution of freshwater is driven by a few large scale climatic factors, for example, the El Niño-Southern Oscillation (ENSO).

Groundwater is now a major source of water for human consumption, supplying nearly half of all drinking water in the world. Groundwater's omnipresence and unique buffer capacity have enabled people to settle and survive in dry areas where rainfall and runoff are scarce or unpredictable. Groundwater is crucial for the livelihoods and food security of over 1 billion rural households in the poorer regions of Africa and Asia,



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and for domestic supplies of a large part of the population elsewhere in the world.

During the twentieth century an unprecedented 'silent revolution' in groundwater abstraction took place across the globe. The global groundwater abstraction rate has at least tripled over the past 50 years, significantly boosting food production and rural development. No matter how large the volumes of water contained in these aquifers may be, the fact that many of them are non-renewable means they can eventually be mined to exhaustion if their use is not managed properly. In some hotspots, the availability of non-renewable groundwater resources has reached critical limits.

Despite these real concerns over unsustainable abstraction rates and pollution, groundwater resources, if carefully managed, can make a major contribution to meeting the demand for water in the future and to adapting to climate change. Investment will be required to improve water measurement and control and, where appropriate, increase surface water and groundwater storage, both in constructed reservoirs and in natural storage in wetlands and soil.

Glaciers act as buffers. Water is released in years of low snowfall and retained as ice in years of heavy snowfall. In the short term, shrinking glaciers add


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water to streamflow over and above annual precipitation and so increase water supply. In the longer term, however, glaciers are expected to disappear as an additional source of water, albeit very slowly.

The quantity of available water is also determined by its quality. Polluted water cannot be used for drinking, bathing, industrial uses or agriculture. The more polluted the water, the greater the cost of treatment required to return it to a useable standard.

Poor water quality damages human health and degrades ecosystem services. The economic costs of poor quality water in countries in the Middle East and North Africa range from 0.5% to 2.5% of GDP.

The preventive and collaborative approach described as Water Safety Planning has demonstrated cost savings and improvements in water quality. It requires the engagement of principal stakeholders, including land users or householders discharging industrial, agricultural or domestic waste into a catchment area; policy-makers from various parts of government overseeing the implementation and enforcement of environmental regulations; and practitioners delivering water to consumers at the tap.

Reducing pressures on water resources

Climate change is of central importance: it is affected by energy production and impacts directly on water. Mitigation measures focus on reducing energy consumption, which would alleviate energy-driven pressures on water demand. Adaptation means planning and preparing for increasing hydrological and extreme weather events including floods, droughts and storms. Other measures likely to affect water consumption by the energy sector are the development of more water-efficient technologies for both primary energy and electricity. Water and energy policies, which are often made in different government departments or ministries, will need to be harmonized, and policy-making become better coordinated.

The main challenge facing the agricultural sector is not as much growing 70% of additional food in 40 years, but making 70% more food available on the plate. Reducing losses in storage and along the value chain would go some way towards offsetting the need for more production (and water). Innovative technologies will also be needed to improve crop yields and drought tolerance, and deliver more efficient ways of using fertilizer and water. Industrialized countries are well placed to take advantage of these technologies, but must also enable the least developed countries to have access to them on equitable and non-discriminatory terms.

For most industrial operations, water has not hitherto been seen as a problem. Improved water management is generally reflected in overall decreased industrial water withdrawals or increased wastewater treatment, highlighting the connection between higher productivity and lower consumption and effluent discharges and reduced pollution. However, industry will not be immune from growing water pressures, the impacts of which will extend beyond factory boundaries to affect workers, customers, suppliers and members of host communities. Industry will need to consider not only its own direct interests but also those of other stakeholders and the natural environment.

It is estimated that over 80% of wastewater worldwide is not collected or treated, and urban settlements are the main source of point-source pollution. The public needs better information on the impact of its consumption on the quantity and quality of water resources. Tools are being developed for managing growing urban demand for water; in particular, integrated urban water management (IUWM), which links freshwater, wastewater and stormwater management within a common resource management structure.

Water's social and environmental impacts

Measures to improve water resource management, increase access to safe drinking water and basic sanitation, and promote hygiene have the potential to improve the quality of life of several billion individuals, reduce child mortality, improve maternal health and reduce the burden of waterborne disease. Supporting women's access to, and their control over, water will in turn improve their access to secure sources of food and livelihoods which will benefit their own health and that of their families.

Water-related disasters are a major obstacle to poverty reduction and to meeting development objectives such as the MDGs. A particularly pressing issue is that of desertification, land degradation and drought (DLDD). Recent estimates suggest that nearly 2 billion hectares of land worldwide – an area twice the size of China – are already seriously degraded, some irreversibly. Globally, DLDD affects 1.5 billion people who live in degrading areas, and is closely associated with poverty. DLDD-induced water scarcity results in food insecurity and malnutrition among affected communities, particularly in developing countries.

Ecosystems underpin the availability of water, including its extremes of drought and flood, and its quality. They deliver multiple benefits (services) that are essential for sustainable development. Many of these key services are derived directly from water, and all are underpinned by it. Trends in ecosystems, including the life they support, are telling us that things are out of balance. Policy-makers and managers need to recognize that ecosystems do not consume water – they supply and recycle it – and water taken from ecosystems unsustainably reduces their ability to deliver the benefits we need ecosystems to provide.

Water management, institutions and capacity development

Understanding the multiple aspects and roles of water is crucial to governing it effectively. Water affects social welfare and economic development within a range of sectors. Water demands and uses are often managed in isolation of each other (which can lead to conflicts between competing sectors) rather than as part of an overarching strategy to make the best use of water throughout society and the economy.

Effective institutions can reduce natural, economic, technical and social uncertainties. However, the diverse structure of water management in dealing with various resource and use/service-related issues is reflected in the complexity and fragmentation of the institutions that exist to govern and manage it. A further problem

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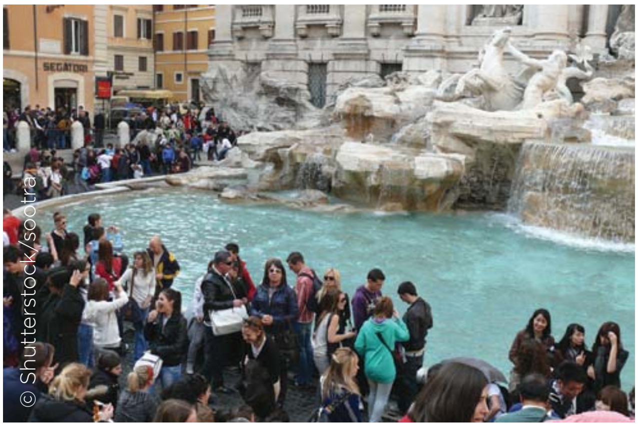
is that many water institutions are still heavily focused on technological and other supply-side solutions. To cope with the necessary changes, such institutions will have to shift their emphasis towards the management of processes and people.

Water cross-cuts all social, economic and environmental activities. Integrated water resources management (IWRM) aims to align water management across all relevant sectors, policies and institutions to achieve national water, food and energy security. It requires different uses of water to be considered alongside each other and provides a structure within which competing interest groups (water utilities, farmers, industry and mining, communities, environmentalists, etc.) can hammer out coherent strategies for meeting future challenges and uncertainties. IWRM involves a broad group of stakeholders in the 'rule-setting' process for the management of water resources, which in the case of transboundary water systems will also involve international collaboration.

Informed decision-making

It is becoming increasingly important to national governments to have reliable and objective information about the state of water resources and how they are used and managed. In this context, the Organisation for Economic Co-operation and Development (OECD) has set as a policy goal 'de-coupling environmental pressures from economic growth'. Trends in water use are an important parameter to be monitored.

Information on water is needed from all parts of society, from local communities to global multilateral organizations, including farmers, urban planners, drinking water and wastewater utilities, disaster managers, business, industry and environmentalists. Data availability is generally particularly poor for groundwater and water quality. It is essential to set up sustainable systems for data collection and dissemination, and to



establish forums for sharing this information. A key objective is to reduce uncertainty about water resources and their use in order to improve the management of risks.

An extensive array of indicators has been developed to monitor the state, use and management of water resources. Alongside trends in water use, the water efficiency of different sectors, measured in terms of output per unit of water use, can be a helpful indicator. At a broader societal level, the widely used concept of national water stress measures the amount of water available to a country per person. To achieve a balanced allocation and protection of water resources, indicators should be chosen to cover regulation (e.g. technical and performance standards) quota-setting, access rules and allocation procedures, as well as economic instruments (especially pricing mechanisms and payments for ecosystem services).

A WWAP Expert Group on Indicators, Monitoring and Reporting (IMR) considered the availability of data and the actions that could be taken to enhance the flow of data. One of its findings was that a limited set of key 'data items' could support a wide range of different indicators.

However, the data required to populate the indicators are seldom systematically or reliably available at a global, national, regional or basin level. Concern about climate change is one of the factors which has led to explicit recognition that the 'stationary hydrology' assumption can no longer be used as the basis for assessment of water availability. This in turn has focused attention on the limited amount of global data on streamflows on which estimates of water resource availability must be based. While there are a great deal of available data on precipitation, which can be measured by remote sensing, changes in runoff to rivers or recharge of groundwater are much harder to measure. The huge resource base derived from remote sensing (validated by hydromet networks and services) has not yet been translated into serious flows of useful processed information about water and its use. For instance, the remote monitoring of indicators of water quality would signal trends in eutrophication and other problems affecting the status of natural ecosystems such as wetlands.

Data on water use are often even more difficult to obtain than information on the state of the resource itself. The direct use of water by field crops can now be reliably assessed using remotely accessed data, but it is more difficult to determine the amount of water actually abstracted from rivers and dams to irrigate fields. Surprisingly little is known about how much water is actually withdrawn and consumed by industry. Because water is cheap and widely distributed its use is often not measured directly, rather estimated using standard assumptions about water consumption in specific industries. There may be an unwillingness to share information. If actual use data are not obtained, it will not be possible to track improvements in water productivity, even if they are substantial.

Economic policy-makers have recognized that water resources have an important but largely unaccounted for influence on national economies. The most effective driver of efforts to improve the flow of information on water will be a demand from policy-makers and decision-makers in socio-economic sectors. There are now significant opportunities for the global community of water practitioners, as well as water users and those members of the wider community with a stake in water, to make substantial improvements in the availability and quality of information about the resource, its use, users, benefits derived from it, how these benefits are allocated, and who bears the costs and negative impacts.

The development of techniques that enable evapotranspiration from crops to be measured directly is an example. Accurate estimates of precipitation can be made using data about signal attenuation between mobile phone towers, which means that telecommunications service providers can help to fill data gaps. The GRACE family of satellites, which has enabled the application of remote gravimetric measurement to determine changes in the total water 'stock' in specific geographical areas, has already demonstrated the potential to monitor changing groundwater reserves in large alluvial basins. A pilot initiative of WWAP, basing the estimate of available water on a combination of observed hydrometeorological and surface elevation data, produces long-term moving averages of total annual renewable water resources (TARWR).

Regional perspectives

Africa

The contribution which water will make to Africa's development is widely recognized. The continent faces endemic poverty, food insecurity and pervasive underdevelopment. Almost all African countries lack the human, economic and institutional capacities to develop and manage their water resources sustainably. Access to improved water supply by both urban and rural populations is still the lowest among the world's regions. Most countries do not take full advantage of available arable lands for agricultural production and irrigation expansion, and hydroelectricity is underdeveloped.

Coverage of drinking water supply in sub-Saharan Africa is barely 60% overall. Coverage in rural areas has grown to 47% in 2008, but has remained static at just over 80% in urban areas over the period since 1990. Only 31% of the population uses improved sanitation facilities and although the proportion of the population practising open defecation is declining, in absolute numbers it increased from 188 million in 1990 to 224 million in 2008. From the mid-1990s to 2008 the number of persons who were malnourished in sub-Saharan Africa increased from 200 million to 350–400 million. Since the mid-1960s, agricultural production has increased by an average of less than 2% annually, while the population has risen at a rate of 3%.

Overall, only one in four people in Africa has electricity. Hydropower supplies a third of Africa's energy, but the region has vast hydropower potential – enough to meet all the continent's electricity needs. Only 3% of its renewable water resources are exploited for hydroelectricity. African countries have begun to address transboundary water issues related to hydro development, such as through power pools like the South African Power Pool (SAPP) and West African Power Pool (WAPP).

Drought in sub-Saharan Africa is the dominant climate risk. It destroys economic livelihoods and farmers' food sources and has a major negative effect on GDP growth in one-third of the countries. Floods are also highly destructive to infrastructure and transportation and flows of goods and services. They contaminate water supplies and increase the risk of epidemics of waterborne diseases such as cholera.

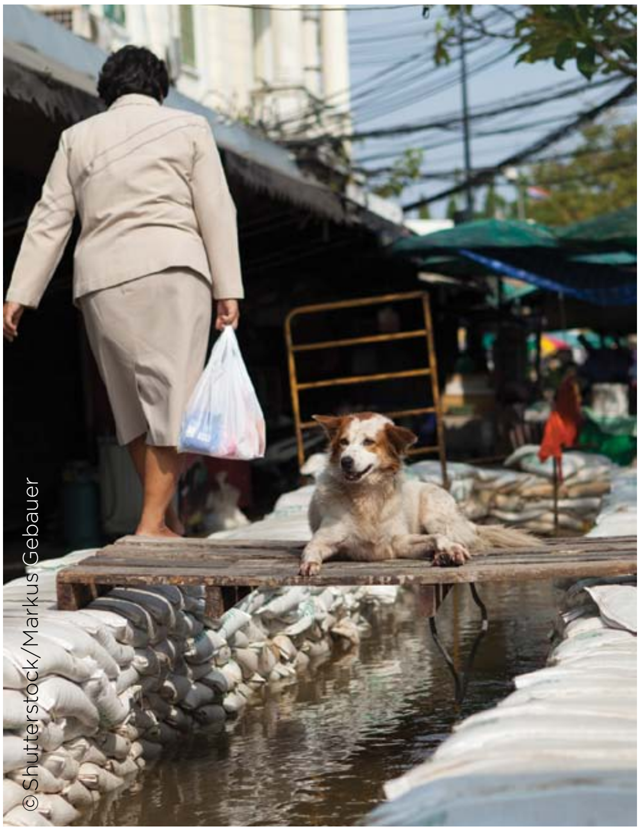
Europe and North America

North Americans are the highest per capita water users in the world, consuming some 2.5 times the European rate. Various estimates indicate that, based on business as usual, approximately 3.5 planet Earths would be needed to sustain a global population achieving the current lifestyle of the average European or North American. However, pockets of water deprivation exist, particularly amongst indigenous people – more than 10,000 homes on reserves in Canada have no indoor plumbing and the water or sewer systems are substandard on one in four reserves. In Europe, some 120 million people do not have access to safe drinking water and even more lack access to sanitation, which results in higher incidences of water-related disease.

An important problem in Europe and North America is the pollution of water courses by agrochemicals, namely nitrogen, phosphorus and pesticides. While legal frameworks exist to regulate this problem, in the drainage basins of the Mediterranean Sea, the East Atlantic Ocean and the Black Sea, anti-pollution enforcement is lagging and water quality suffers as a result.

The Intergovernmental Panel on Climate Change (IPCC) predicts that water stress will increase in Central and Southern Europe, and by the 2070s the number of people affected will rise by 16 to 44 million. Summer flows are likely to decline by up to 80% in Southern Europe and some parts of Central and Eastern Europe. Europe's hydropower potential is expected to drop by an average of 6% over this period. The IPCC considers that in North America climate change will cause increased competition among users for over-allocated water resources.

In the European Union, the Water Framework Directive concluded in 2000, as well as more recent directives on standards and groundwater, represent the only



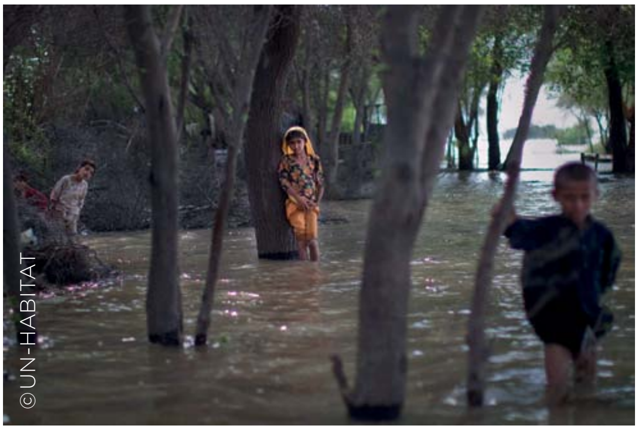
supra-national water arrangements in the world. It has accelerated a historical process of transboundary water management.

Asia and the Pacific

This region is experiencing rapid urbanization, economic growth, industrialization and extensive agricultural development. These trends are, however, accompanied by intensive use of resources that pressurize aquatic ecosystems and affect the region's capacity to meet its water needs. Food security is an urgent issue as two-thirds of the world's hungry people live in Asia. Internal migration and urbanization are driving the rise in the number of megacities and the growing need for municipal water services.

The proportion of the region's population with access to improved drinking water increased from 73% to 88% between 1990 and 2008, an increase of 1.2 billion people. China and India together account for a 47% share of the 1.9 billion people globally that gained access to improved drinking water sources over this period. However, the situation regarding sanitation coverage is much less encouraging – 72% of the 2.6 billion people who do not use improved sanitation facilities live in Asia.

Asia and the Pacific are the regions in the world that are most vulnerable to natural disasters. Much economic and population growth is generated in coastal



and flood-prone areas and the Pacific's small island states are particularly vulnerable to environmental natural hazards such as tropical cyclones, typhoons and earthquakes, and would be highly exposed to rises in sea levels resulting from global warming.

In water resources management, a number of countries in the region are shifting from an emphasis on the short-term development of water infrastructure to a more strategic approach that recognizes the ecological impact of economic development.

Latin America and the Caribbean

Latin America and the Caribbean (LAC) is basically a humid region, although it contains some very arid areas. The pattern of water use in the region can be described as spatially sporadic and highly concentrated in relatively few areas.

The population of the LAC region grew by over 50% between 1970 and 2009, although birth rates are now declining rapidly and population growth is slowing accordingly. The region has seen a massive shift in the relative shares of the population living in rural and urban areas and has seen large intercity migratory flows as the urban population tripled over the past 40 years. Urban growth has led to a high proportion of large cities (with over 1 million inhabitants) and in some cases a high concentration of the population in the one or two largest cities. However, a recent trend has been the rapid growth of intermediate and small cities. An estimated 35% of the population, or some 189 million people, still live in poverty, of whom some 14% are in the very poor social category.

Many LAC countries depend on the export of water-intensive goods and services, including minerals, food and other agricultural products, timber, fish and tourism. Global demand has increased appreciably in recent years. This 'virtual' export of water has important implications for competing water demands in the region. Although most LAC countries enjoy high levels of coverage of improved water and of sanitation, there is a large variation in the quality of services and important differences between rural and urban areas and among countries. Almost 40 million people still lack access to improved water and nearly 120 million to proper sanitation facilities. The majority of those without access to services are poor rural dwellers.

Transboundary water resources pose serious geopolitical problems. LAC has 61 basins and 64 aquifers that cross national borders. Many LAC countries have entered into transboundary water agreements, typically to manage hydropower, but political obstacles have often led to conflicts. There are few examples of agreements for managing shared groundwater.

With relatively weak water management capabilities, the region's poorest countries in Central America, the Caribbean and the Andes will be at the highest risk from the impacts of climate change. On the positive side, lessons learned from adaptation to the consequences of El Niño events have led to technological innovations and increased human capacity that are applicable to water management in the face of climate change.

The Arab and Western Asia Region

About two-thirds of this region's available surface water originates from outside the region and at times this has led to conflict with 'upstream' countries. Water scarcity inevitably leads to concerns about food insecurity given the high demands agriculture makes on water consumption. Imported foodstuffs, particularly grain, account for a sizeable amount of virtual water consumption in this region. Local cereal production has been boosted by the increased exploitation of groundwater for irrigation. However, as aquifers are drawn down, pumping water is increasingly expensive and unsustainable. Against a background of water scarcity, key drivers affecting the region's water resources are population growth and migration; growing income, wealth and consumption; and regional conflicts. Water governance in the region urgently needs strengthening to deal with these challenges.

Climate change is expected to produce increased temperatures and soil aridity and shifts in seasonal rainfall patterns (which are already being experienced in some rainfed agricultural areas such as the Syrian Arab Republic and Tunisia). There is also likely to be more frequent extreme weather events (floods and droughts), reduced snowfall and snow melt in some mountainous regions, and sea level and water salinity rises in coastal aquifers.

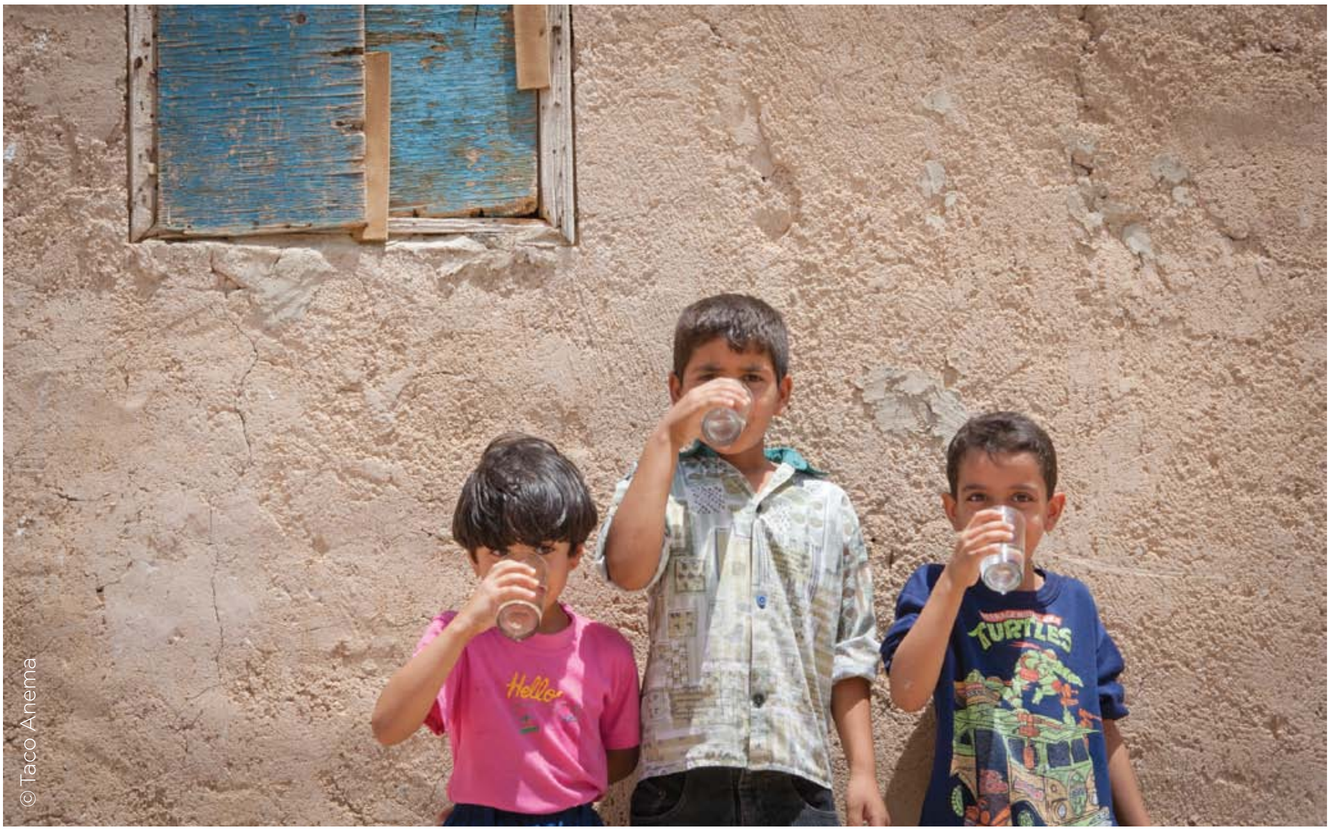
Past conflicts have created large numbers of internally displaced persons, which has increased regional migration and strained water resources and services in receiving areas. Violent conflict has also destroyed water infrastructure at different times in Beirut, Kuwait and Lebanon, absorbing resources needed for rehabilitation.

To defuse potential conflict over water resources, attempts have been made to share scarce waters in a coordinated manner across the region. The League of Arab States created the Arab Ministerial Water Council and an Arab Water Security Strategy. National ministries and authorities responsible for water production are often linked to those for energy, agriculture and irrigation. National water laws have been adopted in a number of countries, many of which are also deploying IWRM.

Regional–global links: Impacts and challenges

The impacts of regional challenges are felt globally. The incidence of natural disasters is increasing in most regions of the world, and frequently affect socio-economic development. Droughts, quite apart from their direct impact on human needs, have a critical impact on agricultural production and have contributed to soaring food prices and shortages. The cost of wheat has almost doubled since the summer of 2010 due to a sharp decrease in world production.

Water shortages contribute to conflicts of varying intensity and scale. Although these may appear localized, they have wider effects, such as displacement, mass migration, disruption of livelihoods, social breakdown and health risks, all of which leave their mark on the global community.



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Part 2:
Managing water under uncertainty and risk

Global political and social systems are changing in unpredictable ways. Technology is evolving, and living standards, consumption patterns and life expectancies are changing. Human populations are growing and moving to expanding urban settings. Consequently, land use and cover is changing, as is the climate. The rate of change of these events is increasing and their long-term impacts are uncertain.

Water is the primary medium through which the impact of these changes in human activity and the climate will be felt. The carbon cycle (the realm of climate change mitigation) and the water cycle (the realm of adaptation) are inter-linked: ecosystems require water to store carbon and by doing so have an impact on water. Without proper adaptation or planning for change, hundreds of millions of people will be at greater risk of hunger, disease, energy shortages and poverty due to water scarcity, pollution or flooding.

As an input to all economic activities, water will be affected by decisions made in a wide range of sectors and domains, which typically have no direct engagement with water policy. Risk will be managed in different ways in each sector or domain. Providing decision-makers with tools that show the broader water resource consequences of alternative ways forward will substantially contribute to better overall management of the resource, with the possibility of reducing adverse impacts.

Managing risk and uncertainty

Risk and uncertainty are inherent in the decisions which water managers and policy-makers must make, and the emerging range of drivers and impacts often lie outside the traditional water arena. The more these risks are understood, the more robustly water systems can be designed and managed to reduce the impact of future variability.

Historically, water planners and engineers have been able to base their decisions on characteristics of the water cycle and hydraulics which could be described within known statistical parameters and stable probability distributions. Today, however, these professionals are having to deal with future probabilities of extremes of events that have not yet been observed and are outside the envelope of variability defined by past events. These uncertainties are due to future changes in population growth and spatial distribution, changing water consumption patterns, socio-economic development, and increasing climatic variability. The latter influences future precipitation, evaporation, groundwater infiltration, surface runoff and channel flow in ways that are difficult to model based on past experience. Furthermore, as water is an input to all economic and social activities, decision-makers need planning tools which reflect the wider consequences of their decisions. Long-term decisions tend to have high fixed costs and are difficult to change or reverse. They include infrastructure investments such as reservoirs and water and sewerage systems.

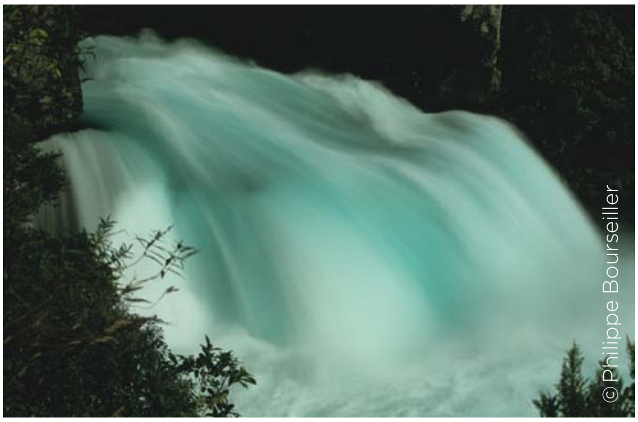
Two approaches for dealing with the extremes of uncertainty now encountered in complex water management problems are *adaptive strategies* and *robust strategies*. An *adaptive strategies* approach selects plans that can be modified to achieve better performance in the light of realized outcomes. These strategies can be responsive to new goals or objectives of system performance as well as to changing inputs over time.

Robust strategies identify the range of future circumstances, and then seek to identify approaches that will work reasonably well across that range. This applies especially to decisions that cannot be easily or cost-effectively modified in the future.

Scenario analysis is also an appropriate and tested approach for dealing with uncertainty. Analysing water issues in the context of sustainable development requires a long-term view that takes into account the evolution of some of the hydrological and social processes involved. Scenarios are hypothetical sequences of events, constructed for the purpose of focusing attention on causal processes, decision points and the unfolding of alternatives – and to branching points at which human actions can decisively affect the future. They are particularly helpful in situations where it is difficult to assign probabilities to possible events or outcomes, whether due to a limited initial understanding of processes involved, or due to the intrinsic indeterminism of complex dynamic systems. WWAP is currently carrying out a project to develop potential scenarios for the world's water resources and their use up to 2050.

Understanding uncertainty and risks associated with key drivers

Traditionally, the statistical analysis of past climatic records has been a fairly reliable basis for predicting the water cycle and its hydrological extremes.



Historical climatic and hydrological information often forms the starting point for water managers and extrapolations of the past are routinely conducted to simulate future hydrological conditions. However, water stress and sustainability are functions of the available water resources and their withdrawal and consumption. Both resources and projected pressures on water resources lie outside the control of water managers. The WWAP World Water Scenarios Project undertook survey-based research on ten drivers of change. The precise relevance of each of these drivers varies in different regions of the world. Participants in these surveys identified and quantified a number of the most likely drivers, summarized below.

Increased water productivity in agriculture has been ranked as the most important development affecting water. Between 1961 and 2001, water productivity for agriculture increased by nearly 100%. Participants estimated that agricultural productivity would be likely to increase another 100% by 2040.

Climate change will affect the hydrological cycle and hence the availability of water. Participants estimated that the number of people at risk from water stress was likely to reach 1.7 billion before 2030 and 2.0 billion by the beginning of the 2030s. A 50% increase in delta land vulnerable to serious flooding is seen as likely to occur by the beginning of the 2040s.

Participants considered that, as a result of infrastructure development, 90% of the global population would probably have reasonable access to a reliable source of *safe drinking water*, and 90% to appropriate *sanitation* facilities, by the beginning of the 2040s.

The widespread adoption of *rainwater harvesting*, combined with simple and cheap ways of purifying the collected water, was also considered a likely development between 2020 and 2030. Better use

of *affordable technology* by agriculturalists to check crops and soil moisture will also increase the efficiency of irrigation schedules.

Population estimates put overall world population size at almost 8 billion by 2034, 9 billion by the beginning of the 2050s and over 10.46 billion beyond this. Population growth could overwhelm past gains in water and sanitation accessibility, particularly in developing countries where recent improvements in access to water supply and sanitation could be more than negated.

The *demand for water* in developing countries could increase by 50% over 2011 levels. Over 40% of countries, mostly low-income countries or those in sub-Saharan Africa and Asia, could experience severe freshwater scarcity by 2020. An important risk is that unequal access to water will create new economic polarities and give rise to political tensions.

The development of online forums on water issues, including local government and civil society, could help reduce the asymmetry of information between user, provider and policy-maker. Networked coordination at the national level to share information and best practices between local water agencies could be achieved in at least 95% of countries between 2020 and 2030. However, it is important that governments should be able to respond to these information flows. There is a concern that resistance from government and vested interests could prevent the necessary flexibility, participation and transparency of governmental policy-making.

Against these risks, the World Water Scenarios Project has constructed various scenarios in which to explore future water availability and its impacts on human well-being and the health of ecosystems that provide life support. The principal causal links have been tentatively identified, and it is useful to examine how certain drivers could interact with each other and how trends accumulate in order to examine possible futures for water resources.

In *one possible future*, the status quo continues, without further intervention. Growth in food demand resulting from population growth and changes in nutritional habits, combined with increased urbanization, lead to a greatly increased demand for water. Expanding human settlements will encroach on fragile or marginal lands, and there will be increased deforestation and pollution. Climate change is expected to result in decreased water availability in many regions, exacerbating economic polarities between water-rich and water-poor countries, as well as between sectors or regions within countries. Much of the burden of these impacts is likely to fall on the poor.

A *second possible future* is one in which technological advances are fully exploited, particularly the trend towards desalinization. Technological developments in agriculture lead to sizeable water conservation. Other technological developments in urban water production and waste handling also contribute to reducing absolute water withdrawals and waste. Rapid uptake of these technologies would be paired with an increased popular appreciation of water scarcity.

A *third possible future* extrapolates current demographic and technology trends, and includes a set of policy interventions that could be adopted over the next two decades. A legally binding international agreement to combat climate change could be in place by 2040, along with significant financing for awareness-raising and adaptation in low-income countries. Because most climate change impacts are felt through water, this would have positive repercussions on the overall levels of financing for water. This could mean high levels of investment in water infrastructure, leading to reductions in waste and increases in sustainable mobilization, as well as increased sanitation network coverage.

Several other policy interventions are considered in this third scenario. Investment in water management and conservation, as well as sanitation, is expected to have multiple poverty-reduction benefits, based on development of solid property regimes, documented land tenure arrangements, and clearly established water rights and allocation systems. Subsidies that encourage inefficient uses of land, water and fertilizers, creating a bias in favour of high water users, would be gradually replaced by flexible, index-based insurance schemes that allow producers to make short-term cropping decisions based on climate variability and extremes. Water-basin institutions and decentralized authorities would be given increased power and resources to effectively manage water within countries. This would promote local and climate-responsive allocation of water among users, facilitation by well-regulated pricing, and innovative water rights trading mechanisms.

The impact of unvalued water on future uncertainties

Given that increasing pressures on water resources are leading to a shortage of water to satisfy all needs, choices must be made about how to share, allocate and reallocate increasingly scarce water within sectors, from one user group to another, or between sectors such as industry, mining, power and tourism. Valuing the many socio-economic benefits of water is essential for improving the decisions of governments, international organizations, the donor community, civil society and other stakeholders. An appreciation of the economic value of water in its different states and uses is a necessary part of effective water management. In the absence of proper valuation water is prone to suffer political neglect and mismanagement. In turn this leads to suboptimal levels of investment in water infrastructure and to the low priority given to water policy in country development programmes, poverty reduction strategies and other policies.

The *price* of water is a financial or fiscal transaction between the provider and the user, which is often closely controlled by public authorities, and often bears little relation to either its value in specific uses or its cost of supply. However, in well-functioning water markets, economic values will establish themselves through trading prices. Where such markets have been created, usually between farmers, prices will typically reflect the value of marginal amounts of water necessary to secure the most valuable, or water-sensitive, uses. A more complete analysis of differential water values is desirable for regulating water trading; for example, when it is in the public interest to allow trading between rights holders. Using water values to inform management and allocation policies does not imply that markets should not be regulated. Public authorities need to intervene to set the rules of the game, ensuring adequate supplies of water and sanitation services to satisfy basic needs and to safeguard public health.

Transforming water management institutions to deal with change

The challenge for water authorities is to move from planning for one defined future to the use of plans responsive to a range of possible future scenarios, all

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uncertain but presenting varying degrees of probability. In this new paradigm, interplay is required between technical specialists, government decision-makers and society more broadly.

IWRM needs to embrace an adaptive approach to management in response to exogenous changes. Another approach is to ask what can be done today to shape a more desirable range of possible futures: by seeking robust projects or strategies that do not require a major revision of current economic and optimization decision rules used in water resources management. Such robust strategies are revised as better information becomes available and they use computer-aided analysis for the interactive exploration of hypotheses, options and possibilities.

As IWRM becomes more adaptive it will involve more multi-sector and multi-disciplinary collaboration. It will also be necessary to look beyond what is traditionally considered water management and link it with decisions made in other linked domains such as land management, agriculture, mining and energy.

Investment and financing in water for a more sustainable future

Investment in water infrastructure is a driver of growth and a key to poverty reduction. To function sustainably, water resources management and the supply of water services must be better funded than at present. Financing will be needed not just for investments in infrastructure, but for essential items such as data collection, analysis and dissemination and to develop human resources and technical capacities. Generating data for policy-makers and managers is a necessary adjunct to good decision-making and to reducing uncertainty, whereas it is currently underfunded and underprovided. Supplying this information can be regarded as a public good for countries, regions and the wider international community. Investment in upgrading national water information bases to systematically report on a few key 'data items' can show good returns and are being targeted for support by international development agencies.

Adequately funded water governance is also essential for reducing uncertainty and managing risks. Effective governance in areas such as environmental controls, groundwater monitoring and abstraction licensing, and monitoring and control of pollution can reduce the risk of overexploitation of water, or of catastrophic surface water pollution and irreversible contamination of aquifers. Some of these governance functions can sometimes be self-financing through abstraction and pollution charges.

There is a range of development funds available for climate change adaptation and mitigation projects, some created especially for this purpose. However, much of the adaptation/mitigation effort will fall to private companies, farmers and households who cannot tap into these development funds. For them, their own resources or commercial finance will be critical. Public agencies have access to specialized climate change funds, a few of which are available for adaptation in water.

Generating finance for water infrastructure and services requires a pragmatic and eclectic approach. Certain types of project, such as wastewater treatment, desalination, and wastewater reclamation and reuse potentially lend themselves to stand-alone commercial ventures funded from equity and other types of commercial finance. However, raising commercial finance for water has become more difficult due to the global financial situation since 2007, which has discouraged new private interest in water infrastructure projects and adversely affected the supply of risk capital and loan financing. Some innovative deals, developed with technical assistance and risk-sharing from donor agencies, are stalled. At the same time, though many national governments are constrained by their fiscal position, others have benefited from strong commodity prices and have used their fiscal resources to invest in infrastructure, including water.

Because most revenues arising from water services are in local currencies, foreign exchange risk is a potential issue for water projects and providers, both private and public. Hedging against devaluation risk is not a practical proposition. The more sustainable long-term solution is to generate more internal revenues from tariffs and to rely as much as possible on local financial and capital markets.

A number of donors and international financial institutions offer risk-sharing products to encourage the growth of local current finance for water and other infrastructure. As a general principle, the risk of financial default can be managed by tailoring financial terms to the risk profile and expected cash flow of the project concerned. For large and complex projects it is becoming common to blend different types of finance (commercial loans, concessionary loans and grants, equity) to achieve an acceptable overall mix.

Responses to risk and uncertainty from a water management perspective

One of the most effective ways of reducing uncertainty is to generate new information about the availability and quality of water, now and in the future, through better data collection, analysis and prediction. This in turn will improve the quality of decisions made in crucial respects.

Spreading risk is another way forward. The International Water Management Institute (IWMI) has proposed that a diversity of water storage schemes should all form part of a balanced portfolio of funded projects. This could range from small-scale rainwater tanks to larger-scale dams, systems that artificially recharge groundwater aquifers, and methods of improving soil capacity to hold more water. Just as modern consumers diversify their financial holdings to reduce risk, smallholder farmers can use a wide array of 'water accounts' to provide a buffer against climate change impacts, including the important threat to food security resulting from periods of drought. Better use should be made of the natural environment as a component of water resources infrastructure; for example, wetlands can reduce peak flood flows and assimilate many organic wastes in the same manner as wastewater treatment plants.

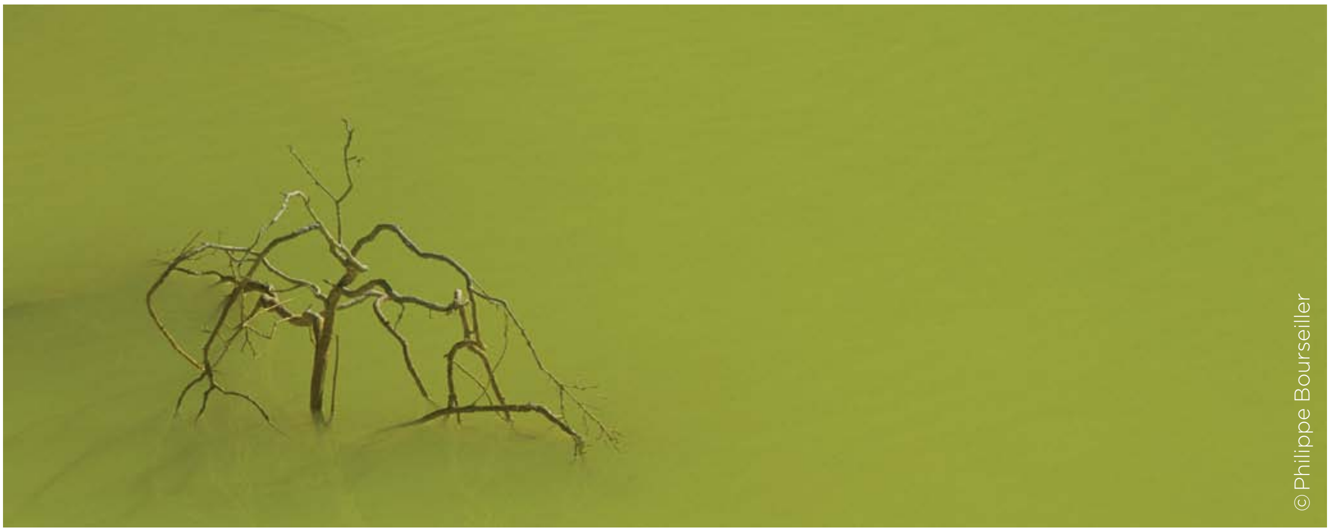
Responses to risks and uncertainties from outside the water box

More development usually means more water use, while higher levels of economic growth often lead to increased water pollution. Different pathways and models of economic growth have different implications, and risk. Conversely, water scarcity could act as a driver of technological change. Water is a key element in 'green growth'.

The water–food–energy nexus illustrates the difficult choices, risks and uncertainties facing policy-makers today. There are many examples of intended or unintended consequences of promoting one cause over others (e.g. food security rather than energy or water security). A key challenge will be to integrate the complex interconnections into response strategies that take into account the various trade-offs and the interests of different stakeholders.

Insurance is one of the oldest risk mitigation mechanisms. Index-based (or parametric) insurance is emerging as a potentially powerful tool for risk management in all sectors. This form of insurance is linked to an index or event, such as rainfall, temperature, humidity or crop yields, rather than to the amount of actual loss. The approach solves some of the problems that limit the application of traditional insurance in developing countries. A key advantage is that the transaction costs are lower. In theory at least, this makes index insurance financially viable for private-sector insurers and affordable to individual producers.

Water treaties or agreements such as those over water allocation in shared transboundary basins can also reduce risks by increasing trust between the various stakeholders. Likewise, agreements and treaties signed for other purposes may help reduce the risks and uncertainties over water where they provide mutual assurance of the other party's behaviour towards other natural resources.



Conclusions

There is a need to replace the old ways of sector-based decision-making with a wider framework that considers the multiple facets of the development nexus, and the multiple risks and uncertainties, costs and benefits of every decision in light of a long-term goal. In this regard, national governments have a major contribution to make by creating stronger, more collaborative, flexible institutions, by adopting appropriate financing mechanisms to ensure the long-term viability of water services and infrastructure, and by ensuring that water considerations are mainstreamed into everyday policy decisions as well as international governance processes. Water managers have a responsibility to continuously inform these processes and to raise awareness of the centrality of water in the development nexus.

The current economic crisis could be seen as an opportunity: it provides an occasion for reflecting on a desired collective future, and it provides a critical glimpse of the interconnections between countries, sectors and policies. Similarly, looking at the future through a water lens also provides the insight needed to make decisions that maximize benefits to people, the environment and the global economy.

The financial, food, fuel and climate crises are, even individually, serious problems, but in combination their effects could be catastrophic for global sustainability. The WWDR4 has sought to provide a new way of looking at our water reality, through the perspective of risk and uncertainty. It has sought to encourage different ways of thinking about the world's collective future by identifying tools and approaches and by demonstrating that win–win scenarios are indeed possible. Political and business leaders as well as water managers, water users and ordinary citizens have a unique opportunity to see past immediate challenges and risks and to effect long-term change towards sustainable prosperity for all, through water.

WWDR4

The United Nations World Water Assessment Programme (WWAP) is hosted by UNESCO and brings together the work of 28 UN-Water members and partners in the triennial *World Water Development Report* (WWDR).

This flagship report is a comprehensive review that gives an overall picture of the world's freshwater resources. It analyses pressures from decisions that drive demand for water and affect its availability. It offers tools and response options to help leaders in government, the private sector and civil society address current and future challenges. It suggests ways in which institutions can be reformed and their behaviour modified, and explores possible sources of financing for the urgently needed investment in water.

The WWDR4 is a milestone within the WWDR series, reporting directly on regions and highlighting hotspots, and it has been mainstreamed for gender equality. It introduces a thematic approach – 'Managing Water under Uncertainty and Risk' – in the context of a world which is changing faster than ever in often unforeseeable ways, with increasing uncertainties and risks. It highlights that historical experience will no longer be sufficient to approximate the relationship between the quantities of available water and shifting future demands.

The WWDR4 also seeks to show that water has a central role in all aspects of economic development and social welfare, and that concerted action via a collective approach of the water-using sectors is needed to ensure water's many benefits are maximized and shared equitably and that water-related development goals are achieved.

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